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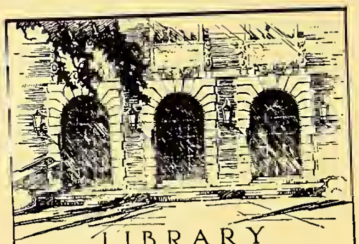

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Arachnida.

the peritoneal cavity, and in many cases it is possible through this incision to operate satisfactorily. No fibre of muscle has been divided, and after the operation the integrity of the belly wall is restored. When suppuration has taken place outside of the appendix, and more room is needed, this incision can be prolonged to give sufficient room: first, by separating the external oblique fibres over a longer distance, the skin incision of course corresponding; and, secondly, by extending the (deep) transverse incision so as to divide the anterior and posterior sheaths of the rectus. The epigastric vessels are easily seen and are to be tied with two ligatures and then divided. The muscle itself is not to be divided, but is to be drawn toward the median line by retractors. By extending McBurney's incision, therefore, the surgeon will obtain ample room for further operative work, except perhaps in cases of exceptionally large inflammatory areas around the appendix. The fascia under the transversalis and the peritoneum are to be opened to an extent justified by the necessities of the case. Should there exist a periappendicular abscess in front of the cæcum, the connective tissue outside of the peritoneum under the transversalis will be œdematous, and if the inflammation be great, œdematous connective tissue will be noticed as soon as the tendon of the external oblique muscle is divided. When the inflammation is confined to the appendix, one or two fingers put through the peritoneal incision will enable the operator to hook up the appendix, which can be drawn into the wound and removed. There is no necessity for making a very small incision. If the excellent advice of McBurney in regard to separating, rather than cutting across, muscular fibre has been followed, the integrity of the abdominal wall is assured after operation.

I find the removal of the appendix is best done as follows: After it has been drawn into the wound, the peritoneal cavity is to be walled off by gauze and the meso-appendix tied off, if voluminous, in segments; if not voluminous, by a single silk ligature. The peritoneal and muscular coats of the appendix are next to be cut circularly at a distance of about one-fourth of an inch from the cæcum, but the incision is not to be extended through the mucous membrane. The muscular and peritoneal tissues are then pushed back, away from the mucous membrane, until the cæcum is reached. An assistant should now grasp this denuded cylindrical tube of mucous membrane by means of two slender artery forceps, while the surgeon makes the dividing incision between the forceps. The free appendix is then to be removed, and the proximal end, close to the cæcum, well touched with pure carbolic acid. The operator may tie the appendix stump, if he feels inclined, but patients seem to do as well without such tying as with it. The stump of the appendix is to be turned into the cæcum, and the peritoneal surfaces of the appendix cuff are to be brought together by means of a Lembert suture, thereby invaginating the stump. If there is any doubt as to what is the condition of affairs, the operator may pass a probe into the cæcum after removal of the artery forceps from the mucous membrane of the appendix, but this, it seems to me, is needless. The wall of the cæcum having been united over the invaginated appendix stump, the same Lembert suture is to be employed in closing in the stump of the meso-appendix. Nothing but peritoneum is then visible. The operator may apply additional sutures to the peritoneal surface, if he feels so inclined. As a rule it is my custom to do this. The wound is cleaned and wiped with gauze, and the gut is pushed back into the abdominal cavity. The peritoneum is then sutured with fine silk, and the two layers of muscle are united separately with silver wire or other material, as the operator prefers. Finally, the skin edges are brought together. Silkworm gut or silver is my preference here. When a periappendicular abscess exists, and I find it necessary to drain the cavity, I bring the ends of the gauze to the surface for drainage, and I close the edges of the wound lightly with layers of removable sutures; for when drainage is employed, my buried sutures are apt to become infected and to give trouble, as drainage precludes absolute cleanliness. If the appendix is swollen and stiff and cannot be invaginated, it is a good plan to tie a string around the base, to cut off that part of the appendix which is distal to the string, and then to leave the string to come away with the gauze packing with which the abscess cavity is lightly filled.

It is very comfortable for the operator to know that the appendix has been removed and that that source of trouble is eliminated from consideration. Whenever, therefore, it is possible to do so, the appendix is to be taken away. But it cannot be done in a certain number of cases without serious danger to the patient; hence in such cases it must be left. Sometimes no trouble is ever experienced from an appendix which has not been seen; but in other cases it may be necessary to do a second operation for the removal of the appendix. An operation is incomplete without the removal of the appendix, but the incompleteness of the operation is less dangerous than is the search for the appendix and the consequent tearing up of adhesions, with possible general infection.

A second operation is undertaken when the inflammatory area is in a quiescent state. Secondary operations and those undertaken for chronic appendicitis are very successful. When general septic peritonitis is present, free opening of the belly is necessary, for the preservation of life takes precedence of every other consideration. Hence the opening into the belly will be effected by an incision sufficiently long to enable the operator to reach all the seat of disease. Pus and fæces are to be evacuated; the whole peritoneal cavity is to be carefully cleaned, dry gauze or gauze wrung out in hot salt solution being used for the purpose; any lymph that may be present should be removed when possible; and it may be thought best (although I have not done it) to wash out the peritoneal cavity. Hot salt solution of course will be employed for this purpose. I think I have had as good results by using dry gauze, or gauze wrung out, as stated already, in hot salt solution. The places where pus must be sought for and removed are the following: the outer side of the ascending colon, below the liver, the pelvic cavity, the side of the rectum, and between the folds of the small intestine. If necessary, the intestines are to be taken from the belly cavity, wiped and cleaned outside, but much shock follows such evisceration. The pelvis is the region which specially requires to be examined and cleaned. After the peritoneum has been cleaned, I think the recovery of the patient is aided by laying large strands of gauze in every direction in the abdomen, as has been already referred to. The edges of the incision are to be left wide open. There is scarcely a limit to the number of strands of gauze which a general peritoneal infection may call for. It may be wise in some cases, in order to provide more direct drainage, to make an opening at the back of the belly through the lumbar region.

In general septic peritonitis the bowels usually refuse to act, and, when this is the case, it may be well, as was first suggested by Dr. McCosh, of New York, to inject into the upper part of the small intestine, before the abdomen is closed, a couple of ounces of Rochelle salts dissolved in water. In order to accomplish this it will be necessary first to pass a small cannula through the intestinal wall. Then, after all the solution has been injected, the hole made by the cannula can be closed by a single Lembert's suture.

Operation for Chronic Appendicitis.—The best time for operating, in a case of recurrent attacks of appendicitis, is during the interval between two attacks, say two or three weeks after the subsidence of the first of these two, provided it has not been an attack of unusual severity. In the latter case the operation should be deferred for a somewhat longer period. The reason why an operation should not be done sooner is that sufficient time must be allowed to elapse in order that any periappendicular lymph may be absorbed, that any pus that may have collected within the appendix may have time to escape

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into the cæcum, and finally that any remaining inflammation may subside completely before the abdomen is opened. It is interesting to note that when inflammation has been excessive, an operation undertaken a number of weeks afterward will find the adhesions thin and weak. It may be expedient to wait even longer, but such a waiting should be permitted only when the patient is directly under the eye of the surgeon, who can intervene at any moment, should another attack occur.

As the steps of the operation have already been described, it will not be necessary to go over this ground a second time. I will simply add that in these chronic cases, especially if the inflammatory attacks have been of a somewhat severe character, it is often a difficult matter to find the appendix, or, if we do find it, to recognize at what point its free end lies. In such cases, the shortest way is probably to divide the appendix across, between two pairs of artery forceps, and then to work each end free from adhesions. In this way there will be no special difficulty in reaching the point where the appendix springs from the cæcum. Whenever this can be done we should cover raw surfaces over with peritoneum.

L. McLane Tiffany.

APYONIM.—This is a yellow, crystalline powder, introduced as a substitute for auromine (yellow pyoktanin) in ophthalmic practice. It is slightly soluble in water, freely so in alcohol, and it is used in one-per-cent. aqueous solution as an antiseptic and stimulant in conjunctival disease, and in purulent keratitis.

W. A. Bastedo.

AQUIFOLIACEÆ or **ILICINEÆ.**—(The Ilex or Holly family.) A family of three genera and some two hundred species, chiefly of North and South America. It is chiefly notable for the presence of an appreciable amount of caffeine in the leaves of at least two species, on account of which they have been used as beverages (see *Maté* and *Cassine*). Other species have been used as bitter tonics and alteratives (see *Alder, Black,* and *Holly*).

H. H. Rusby.

ARACEÆ or **AROIDEÆ.**—(The Arum family.) A large family, of more than one hundred genera, growing mostly in the tropics of both hemispheres. Many species, as the cultivated *calla,* are highly ornamental. *Calocasia* produces an important starch-yielding corm, *monstera,* an edible fruit. Many of the tropical species are known as poisons, but their constituents and actions are little known. It is remarkable that a few northern species in the genera *spathyema, acorus, arum,* and *arisæma,* should represent about all the medicinal contributions of the family, and more active agents may be expected to be made known in it in future.

H. H. Rusby.

ARACHNIDA.*—In the branch or phylum Arthropoda, characterized by bilateral symmetry, by metameric segmentation of a heteronomous type, and by the possession of jointed appendages, typically a single pair for each metamere of the body, may be distinguished five great groups: the Crustacea, including crabs, lobsters, water fleas, etc.; the Onychophora, including but a single genus, Peripatus; the Myriapoda, including millipeds, centipeds, etc.; the Insecta, including the true insects; and the Arachnida or Arachnoidea. The latter may be defined as air-breathing arthropods, characterized by the fusion of head and thorax into a single region, the cephalothorax, which is without antennæ, but bears two pairs of appendages more or less closely connected with the mouth, and four pairs of walking legs. The abdomen, which may or may not be segmented, is usually distinct from the cephalothorax, though in the mites it is fused with it.

The class Arachnida is subdivided by various authorities into from seven to nine orders, among which are the Scorpionida or true scorpions, the Pseudoscorpionida or book-scorpions, the Phalangida or "Daddy Long-legs," the Araneida or true spiders, the Acarida or mites, and the Linguatulida.

The true scorpions have the power to inflict a painful wound by the sting located at the tip of the abdomen. In the case of large tropical species the effect of the sting may even cause the death of small children, but only in the most exceptional cases does it seriously affect an adult. There is injected at the time a quantity of poison from a gland in the last joint of the abdomen; its action is in general to irritate nerve centres while at the same time producing paralysis of motor nerves. The sting of the smaller species found in the United States is harmless, giving rise to a slight irritation, which lasts at most seven or eight days. Mr. Herbert H. Smith, the well-known collector in South and Central America and the West Indies, after enumerating symptoms and results in a number of carefully observed instances, says: "Probably death might result in some cases, as (if reports are true) it does, rarely, from bee stings. . . . My wife was stung by a small one; the wound was exceedingly painful. By the advice of a servant, she held the finger for an hour in hot sweet oil, mixed with an equal measure of laudanum. There was no swelling and three hours after all pain had left her."

Among the spiders also there are those that are able to pierce the human skin by the action of the jaws or chelicerae which also contain the orifices of a pair of poison glands. The effect of a spider's bite on an adult has, however, been much exaggerated; of itself the bite produces at most a slight dermal swelling which soon disappears. The large hairy theraphosids, popularly known as tarantulas, are not to be called dangerous. Their bite is painful, but the inflammation, though often violent, subsides rapidly. On the other hand, several cases on record of death from spider's bite have been traced to a small spider (*Latrodectus mactans*) which is related to supposedly poisonous species in other countries of the world, and it is not unlikely that the spiders of this genus secrete a more powerful fluid than others. The condition of the patient, his susceptibility to poison, and other important facts are not on record in these cases, and it may happen that the chance introduction of extraneous matter through the bite has given rise to the more serious and rarely to the fatal results noted. There are no spiders in this country of which it may positively be affirmed that they are venomous, though certain South American species enjoy an evil reputation which is undoubtedly well founded.

Order Linguatulida.—The highly modified forms included in this group have a certain superficial resemblance to tapeworms, from which, however, they differ radically in structure. Their closest affinities are doubtless to be found among the arachnids of which they are here considered as an order.

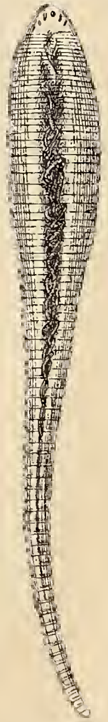

Fig. 243.—Linguatula rhinaria, female. Natural size. (After Braun.)

The body (Fig. 243) is elongate, cylindrical or flattened; the anterior end (cephalothorax) is more or less clearly marked off from the rest (abdomen), which is subdivided by annulations variable in number and distinctness. At the blunter, anterior end the mouth is located on the ventral surface and provided on either side with two protractile hooks, contained in sheaths or pockets. These hooks represent the mouth parts of other arachnids, while other appendages are entirely lacking. There is no special respiratory apparatus, and the so-called stigmata are but the orifices of dermal glands. At the posterior end may be found the anal opening.

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* A general discussion of parasitism and its effects will be found under the heading *Parasites.*

The linguatules are of separate sexes, the males being much the smaller. The female genital pore is located near the anus, the male on the ventral surface near the anterior end of the abdomen. The adults live in the nasal cavities and lungs of mammals or reptiles, and the eggs, produced here in large numbers, must be imported by chance into a suitable secondary host in which they give rise to tetrapod, acariform embryos (Fig. 244, *b*) that metamorphose into a second stage (nymph, Fig. 244, *c*), manifesting the main features of the adult. By a migration usually semi-passive, this form reaches the primary host and attains full development in it.

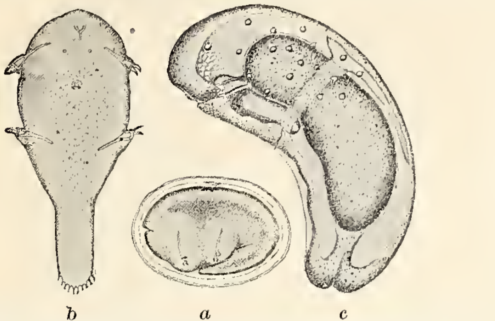

FIG. 244.—Linguatula rhinaria; Stages of Development. (After Leuckart.) *a*, Egg with embryo; *b*, free embryo; *c*, nymph or pupa. Magnified.

Linguatula Fröhlich.—Body flattened, with arched dorsum and crenated margins. Body cavity extending into the lateral regions of the rings (pectinate).

Linguatula rhinaria Pilger = *Pentastoma tænioides* Rud.—Larva = *P. denticulatum* Rud. and *P. serratum* Fröhlich.—Body lanceolate, attenuated posteriad; head rounded, annuli circa 90, hooks acuminate, enlarged toward the base, with basal joint elongated proximad. Female 80–100 mm. long, 8–10 mm. broad anteriorly, 2 mm. posteriorly. Male 18–20 mm. long by 3 mm. broad, decreasing to 0.5 mm.

The adult inhabits the nasal cavities of many mammals, particularly the carnivora, among which the dog is perhaps most commonly infested. The larva occurs in the viscera of the herbivorous mammals. The masses of eggs containing well-developed embryos are deposited by the adult female in the nasal mucus and distributed over grass, etc., with which they are swallowed chiefly by rabbits, but even, as on salads, by man himself. Hatched in the stomach the larvæ penetrate the intestinal wall and encyst in liver or mesentery, where after several ecdyses covering a period of from five to six months, they reach the second stage, characterized by the rows of retrorse spines on each annulus. From the liver they may, as some maintain, wander out actively and if eaten by a dog reach the nasal cavities directly; or they may await the consumption of the flesh by some carnivorous form, in which case they are set free in the stomach and wander through the tissue to the lung and thence by the air passages to their final location. Some authorities deny the possibility of the larva deserting its cyst and wandering out, and maintain that the transmission is always passive.

Rare instances of the occurrence of the adult in man are on record, probably due to the consumption of poorly cooked flesh (mutton) containing the larvæ. The larva (Fig. 245) has been reported frequently as a human parasite, chiefly from Germany and Austria. Most commonly found in the liver, it has also been met with in other viscera. Here it occurs in sharply defined yellow tumors, embedded in the substance of the liver or protruding somewhat from its surface. The tough capsule contains caseous or calcareous contents, and varies in diameter from about 1 cm. to the size of a pea. The capsules are less frequently found scattered irregularly over the surface of the peritoneum. The parasite is probably innocuous, as its presence has not been suspected previous to autopsies, at which Zenker found it in Dresden 9 times in 168 cases, Heschl at Vienna 5 times in 20; Klebs at Basel, however, only twice in 1,914 cases. I have found no records of its presence in man in this country, although it has been reported rarely from other hosts (rabbit and cattle).

Porocephalus.—Body cylindrical; body cavity continuous.

Porocephalus moniliformis Diesing.—Larva = *Pentastomum constrictum* von Siebold. Annuli about 20, separated from one another by a wide interval. Female 70–95 mm. in length, 6–7 mm. broad, male 13–17 mm. in length.

The adult is very incompletely known; it occurs in the African pythons. The larva has been reported from monkeys and the giraffe. It has also been found several times at autopsies of negroes in Egypt and even of English soldiers in African colonies. Since it was found encysted in the liver, and death resulted from peritonitis, there is room for the belief of some authorities that the parasites could not have been the cause, but were merely accidentally present in these cases.

Order ACARIDA.—The mites are throughout of small size, even the largest ticks attaining a length of only half an inch and the majority being but a fraction of this. The body is circular or oval in outline, with flattened ventral surface and arched dorsal. Ordinarily it manifests no separation into parts, though in some forms a distinct groove makes two regions distinguishable. While the skin is commonly marked by transverse striations or folds, traces of metameric segmentation are only rarely to be found. The chitinous covering is frequently provided with plates or shields, and bristles are characteristically present. A small projection (rostrum or capitulum) carries the mouth parts, which are often more or less fused into a beak and modified for biting, piercing, or sucking. As mouth parts are distinguished (1) the mandibles or chelicerae; (2) maxillipeds or pedipalpi, the most prominent part of which are the maxillary palps, jointed, highly mobile structures, located at the sides of the mandibles. The lower lip (hypostome), anterior and inferior to the maxillæ, is ordinarily fused to their bases.

The four pairs of legs, composed of from three to eight joints each, are terminated by claws, bristles, or suckers of various sorts. They may be attached directly to the skin or reinforced by a chitinous framework (epimeres) which may join to form a median ventral ridge (sternum). A special respiratory (tracheal) system is lacking in most parasites, though present in some; it opens by paired stigmata with sieve-plate coverings (peritremes) the location of which is characteristic for various groups. Eyes are also usually wanting in the parasitic forms.

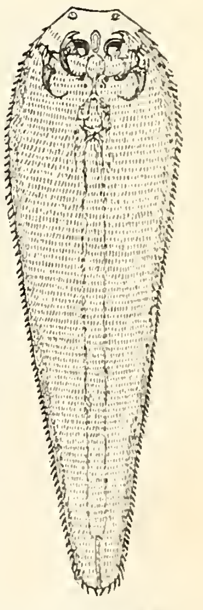

FIG. 245.—Linguatula denticulata, Larva of L. rhinaria. (After Leuckart.) Magnified.

The separate sexes may be distinguished generally by difference in size; in some forms a marked sexual dimorphism exists. The genital orifice is surrounded by a system of chitinous thickenings known in the male as the epiandrium and in the female as the epigynium. The vulva serves as birth opening, whereas a special copulatory orifice occurs at the posterior end of the abdomen. The acarida are usually oviparous, and from the egg emerges a hexapod larva which metamorphoses into an octopod nymph, and finally by the development of the sexual organs becomes adult. This metamorphosis is accompanied by a variable number of moults, and in the Sarcoptidæ by histolysis and complete regeneration of the animal at each ecdysis.

The following table, taken from Railliet, will be convenient in recognizing the various sub-orders and families:

Body elongated. **Vermiformia.**	No tracheæ. Legs with epimeres.	Two pairs of legs. Palpi unarmed. Mandibles styliform.	Phytoptidæ.
		Four pairs of legs. Palpi uncinate. Mandibles styliform.	Demodicidæ.
Body compressed. **Acarina.**	No tracheæ. **Astigmata.** Legs with epimeres.	Palpi joined at base, unarmed. Mandibles chelate.	Sarcoptidæ.
	Tracheæ opening in the anterior portion of the body, atrophied in the aquatic forms. **Prostigmata.** Legs with epimeres.	Palpi free, unarmed, antenniform. Mandibles chelate.	Bdellidæ.
		Palpi free, armed (rapaci). Mandibles with hooks, or styliform.	Marine: Halicaridæ. Freshwater: Hydrachnidæ. Terrestrial: Trombidiidæ.
	Tracheæ opening in the posterior portion of the body, at the base of the legs, sometimes atrophied. **Metastigmata.** Legs without epimeres.	Palpi free fusiform, mandibles chelate.	Oribatidæ.
		Palpi free, filiform or valvate. Mandibles, pseudo-chelate.	Ixodidæ.
		Palpi free, filiform. Mandibles chelate.	Gamasidæ.

Demodicidæ (the Follicle Mites).—Small, elongated mites; anterior region undivided, in adult with rostrum and four pairs of short legs; the posterior transversely striated, without appendages. Tracheæ, stigmata, and eyes wanting. No marked sexual dimorphism. Oviparous. Larva without legs or with three pairs of tubercles, nymph with four pairs of rudimentary legs. Parasites of hair follicles and sebaceous glands of mammalia. Only a single genus with several species.

Demodex folliculorum (G. Simon).=*D. foll.* var. *hominis* auct.; *Steatozoon foll.* E. Wilson. Rostrum short, anterior region of body approximately one-third of total length. Egg cordiform. Male 0.3 mm. long, 0.4 mm. broad; female 0.38 mm. by 0.045 mm.

This form, which presents a characteristic appearance (Fig. 246), is a common parasite of the sebaceous glands of the human skin. It is easily discovered in the sebum from the glands of the nose, lips, and forehead; also in the ceruminous and Meibomian glands, and from the abdominal and pubic regions. Normally the mites rest in the gland, head inward (Fig. 247), and but a few are present in each gland; occasional increase in numbers is said to give rise to stoppage of the duct and from five to twenty may be found in a comedo plug. The statements of some authors, according to which these parasites occur in two-thirds of the persons examined, are held by other investigators to be far beyond the usual percentage of infection. Precise data are lacking. Henle, who discovered this species in 1841, obtained living specimens of the mite from a cadaver six days after death. In spite of the fact that this species is difficult to distinguish from related forms of the dog, cat, and other domestic animals, with a single doubtful exception, no case of infection transmitted in either direction is on record, and all efforts to accomplish this experimentally have failed.

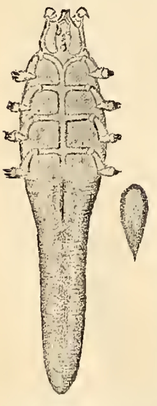
FIG. 246.—Demodex canis. Ventral view of female and of egg. × 100 diameters. (After Mégnin.)

Although *D. canis* gives rise in the dog to a serious dermal disease (Fig. 247) which is rather difficult to handle, no similar difficulty is reported for man with *D. folliculorum*, even in the case of those individuals habitually regardless of personal cleanliness; and an etiological relation between these mites and acne, as maintained by various observers, has not been satisfactorily demonstrated.

Sarcoptidæ.—Small, pale mites, with soft body, not elongated, separated into two regions by a more or less distinct transverse groove. Mandibles chelate, maxillary palpi styliform. Four pairs of five-jointed legs with epimera, in two groups corresponding to the regions of the body, terminal joints (tarsi) with one or two claws, a sucker, or both, or with long bristle. Tracheæ wanting. Sexual dimorphism general. Metamorphosis with hexapod larva and two nymphs, often complicated by the appearance of a hypopial nymph.

Of the seven sub-families only the Sarcoptinæ or itch mites, and the Tyroglyphinæ or cheese mites, are of importance here.

Sarcoptinæ (the Itch Mites).—Parasitic mites with transversely striated integument, with campanulate pedunculate tarsal sucker, often atrophied and replaced by bristles on the third and fourth pairs of legs. Vulva transverse. Found in the skin of mammals and birds, where they produce the various forms of scab and itch.

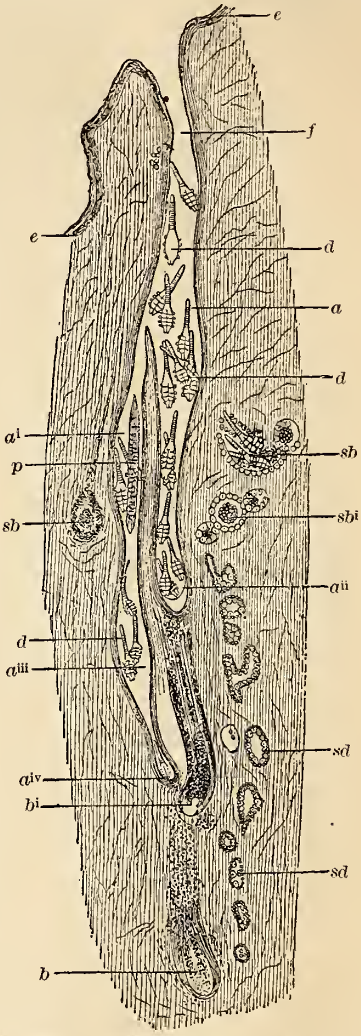

FIG. 247.—Transsection of Skin of Dog, Showing Demodex canis in Position in Hair Follicle and also in Sebaceous Gland. (After Laulanié, from Neumann.) *e*, Epidermis; *f*, hair follicle containing two hairs, *p*, the bulbs of which can be distinguished at *b* and b^i; at the points, *a*, a^i, a^{ii}, a^{iii} and a^{iv}, the follicle has undergone dilatation, by reason of the accumulation of the follicle mites, *d*; *sb*, sebaceous glands, one of which (sb^i) contains the mites; *sd*, sudoriferous glands. × 40 diameters.

Sarcoptes (the Itch Mite of Mammals).—Body round or slightly oval. Rostrum short, and thick; posterior feet entirely or nearly hidden by the body. Tarsal suckers with long, simple peduncle; in female on the first and second pairs of legs, in the male also on the fourth pair. Anus terminal.

Some authors distinguish but a single species with numerous varieties; it seems better, however, in spite of the often insignificant and in part inconstant specific differences thus far known, to follow the later authorities in regarding these forms as different species, even though physiological characters must still be used in part for their distinction. They apparently do not interbreed, and certainly are permanent only on the appropriate host from which in some cases they cannot be transferred to any other, even for a short time, though usually such transfer results in temporary existence without the disease reaching a serious stage and often disappearing spontaneously.

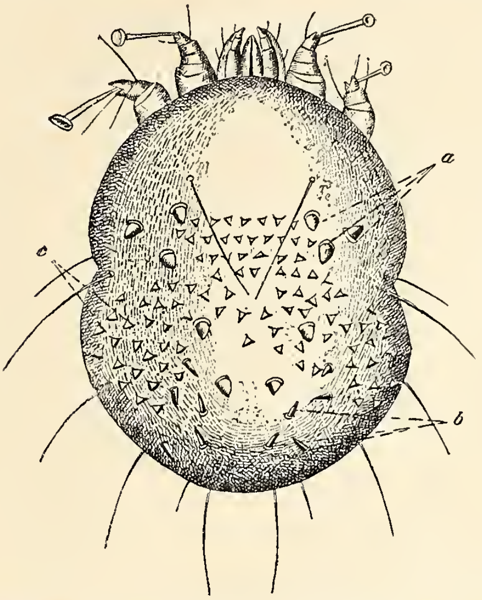

FIG. 248.—Sarcoptes scabiei, female, in Dorsal Aspect. (After Canestrini.) × 130 diameters. *a*, *b*, *c*, Scales.

Sarcoptes scabiei (de Geer) (the Human Itch).=*Acarus siro, A. exulcerans,* Linn.; *Acarus scabiei* de Geer; *Sarcoptes hominis* Hering; *S. sc.* var. *hominis* Mégnin. Dorsal scales pointed, longer than broad. Anterior projections of epiandrium short, scarcely reaching the epimeres. Posterior spines long, pointed. Male (Fig. 249) 0.2–0.24 mm. long, 0.15–0.2 mm. broad; female (Fig. 248) 0.3 to 0.45 mm. long, 0.25 to 0.35 mm. broad.

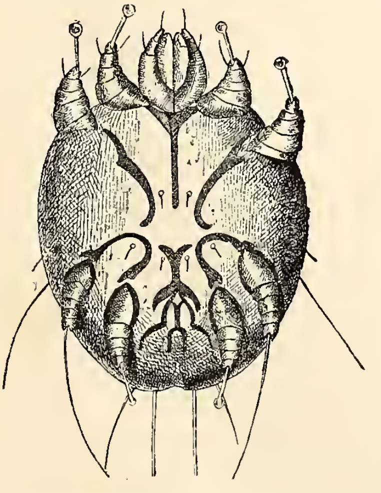

FIG. 249.—Sarcoptes scabiei, male, from Ventral Surface. × 200 diameters. (After Canestrini.)

The history of the disease caused by the itch mite is connected with some of the most momentous disputes in medicine. The complaint is recorded in the earliest writings, and the mite may have been known to Aristotle; but the Arabian physicians in the twelfth century were the first to state clearly the existence of a minute characteristic animal which could be removed from the skin and "cracked" on the finger nail. The galleries bored in the skin were discovered in the fourteenth century, and the mite described and figured clearly in the seventeenth, while in a letter to the famous Italian anatomist Redi, in 1687, Bonomo and Cestoni gave a precise description and figures of the mites and their eggs, inferring correctly that the animals were of separate sexes and were the actual cause of the disease, so that a cure depended upon their complete destruction. Others of prominence in dermatology, however, attributed the trouble rather to "destructive juices," either denying the existence of the mites or their relation to the itch, or holding that a poison was inoculated into the blood by their bite. Early in this century the French Academy offered a prize for the rediscovery of the mite, whereupon a certain Dr. Gales palmed off cheese mites on a learned jury, pocketing both the medals and the prize! Finally, in 1834, Renucci demonstrated in Paris the method by which Corsican women were accustomed to remove the mite on the point of a needle from the end of its tunnel, and thus established its actual presence in the disease. The male was discovered by Krämer in 1845, and the pathology of the disease established upon unimpeachable experimental and clinical evidence particularly by Hebra.

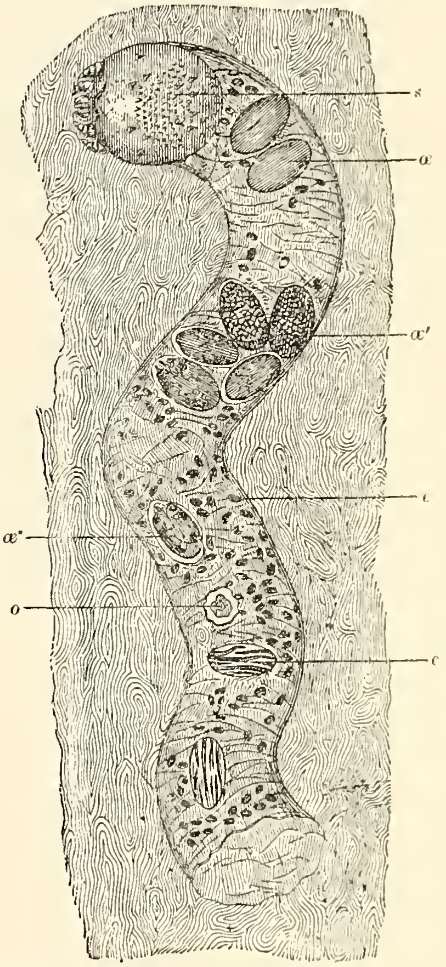

FIG. 250.—Sarcoptes scabiei. Impregnated female (*s*) in cuniculus. (After Railliet; semi-diagrammatic figure adapted from Gerlach.) *oe*, *oe'*, *oe''*, Eggs, those farther away from the mite being older; *c*, an empty egg shell; *o*, orifice through which a larva has escaped; *e*, excrementa.

The mite appears to the naked eye white and glistening, and was aptly described by Bonimo as like a little bladder of water. Viewed under the microscope there is seen a tortoise-shaped head with a pair of short, heavy legs on either side, which have a framework of chitinous bands like the garters of an Italian bandit. The third and fourth pairs of legs are concealed under the posterior margin of the body. The male is much smaller than the female and has the fourth pair of legs terminated by a sucker instead of the bristle which is on the fourth pair in the female. There is also on the ventral surface of the male a complicated chitinous framework wanting in the female.

The human itch mite lives in the skin in which the female tunnels an irregular winding passage, where she passes her entire existence (Fig. 250). These burrows vary in length from a few millimetres to two or more centimetres and are excavated preferably where the skin is thin, as between the fingers, in elbow or knee joint, on mammæ or penis. The gallery, directed first downward through the stratum corneum, is extended through the softer cells of the Malpighian layer just above the papillæ. Eggs and fecal matter fill the most of this tunnel, at the inner end of which may be found the female. The male is much rarer; its existence is passed on the surface of the skin, hiding under scales and in furrows. After an incubation of only a few days there emerges from the egg a hexapod larva, which bores through the roof of the tunnel and gains the surface of the skin, where after three or four moults and the acquirement of a fourth pair of legs the development of the sexual organs is completed. Copulation is followed by the last moult on the part of the female. The latter now pregnant, begins the construction of a gallery in the epidermis (Fig. 251) and once buried in the skin, the recurved dorsal spines prevent her escape.

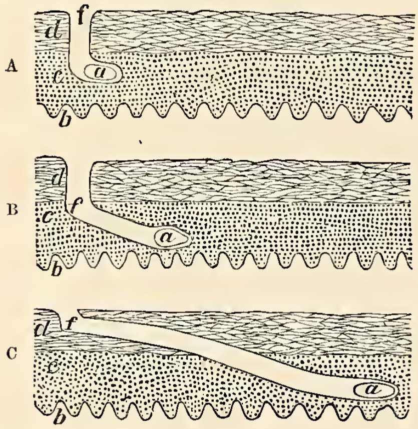

FIG. 251.—Acarian Furrows. *a*, Position of mite; A, the mite has gone down beneath the epidermis; B, the mite has commenced to dig a longitudinal burrow, and the place (*f*) where it was in A, has by the growth of cells come up nearer to the surface; C, the point (*f*) has come up to the surface, while the mite has gone along farther with its burrow. (After Jeffries.)

This species is probably distributed over the entire world; it is very common on the Continent and among the poor in England where it constitutes 8 per cent. of dermatological cases in hospital practice and 3 per cent. in private practice. It is much rarer in the United States and is most frequent in the East; in New York Bulkley had 2 per cent. in the hospital and one-fourth of one per cent. in private practice. In Boston White noted an increase from 9 cases in 1880 to 165 in 1888. Of 318,500 cases recorded by the United States Dermatological Association within a period of a little over twenty-one years (from July, 1877, to January, 1898), it was found in 3.66 per cent. of the total number. Although rare under ordinary circumstances, it increases rapidly under conditions of crowding; thus in 1893, the year of the Chicago Exposition, 901 cases were reported in the United States, while in 1895 the total was only 383 cases. Where such crowding is combined with faulty sanitary conditions, it becomes epidemic in a severe form. Thus during the Civil War, the "army itch," "Jackson's itch," and "seven years' itch," which are merely aggravated forms of the disease, followed the movements of the troops.

The disease is produced by the transfer of the parasite by actual contact from an infected person to one not infected. Such infection must transport both sexes, or at least pregnant females, and under such conditions that they can successfully form burrows. In spite of the fact that in large continental hospitals and clinics, yearly thousands of cases are treated and handled by nurses and students without any precautions whatever in the way of disinfection, no trouble is experienced from the disease.

Infection is easily and most commonly brought about by long-continued and intimate contact, and the nocturnal habits assigned by some to these mites are due to their increased activity under the influence of the warmth of the bed. The disease is also most common among men and of such classes and occupations as are wont to sleep together. A transient infection may be induced by the transfer of this species to the horse, dog, or ape, but the cat is apparently immune toward it.

The itch mite excites at first only a moderate irritation, which gradually grows in intensity and becomes an extensive pruritus, accompanied by eczematic inflammation with the formation of papules and vesicles. The malady increases in severity with duration, and especially as the result of scratching, until it may acquire the character of a severe eczema, the vesicles and pustules being associated with extreme excoriations and the formation of crusts. The itch may be confused with eczema and pediculosis, which latter may in fact coexist with it.

The first step in the treatment of the itch is the absolute destruction of the entire colony of mites and their eggs, for which purpose various sulphur ointments are successfully employed. Naphthol is also highly recommended. In severe cases some eczema remains to be treated after the destruction of the mites.

It is important to record here from Nuttall the view of Joly that the itch mites may serve at times as carriers of lepra bacilli. In parts of Norway where much leprosy exists, these mites are also abundant, and, together with pediculi, they are usually found among the poorer classes in Algeria, from which the greatest number of lepers come. "In the Soudan the sarcoptes occur on almost all the dogs [most probably not the *S. scabiei*—W.], and often attack the natives amongst whom there are numerous lepers. It seems to me that the possibility of this mode of transfer cannot be denied, and it is also conceivable that the pathological changes produced in the skin by the parasites may even favor the multiplication of the lepra bacilli."

Sarcoptes scabieicrustosæ (Fürstb.) (Norway Itch Mites).—*S. scabiei* var. *lupi* Mégnin. Dorsal scales obtuse. Anterior projections of epiandrium well developed, reaching the epimeres. Posterior spines long, pointed, easily bent. Male 0.17 by 0.15 mm.; female 0.41 by 0.34 mm.

This form, though much like the preceding, produces such radically dissimilar effects on the human skin that we are forced to regard it as a distinct species. It was first discovered in Christiania, whence the name Norway itch, by which it is commonly known, though cases have been reported in most European nations and one from this country (Indianapolis) by Hessler.

The malady is easily distinguished from the common itch by the formation of coarse crusts, which, however, do not usually make their appearance for some years. This gives color to the view that this form of the itch finds its explanation in individual differences on the part of the host rather than of the parasite. Opposed to this view is the formation of crusts several millimetres in thickness and several centimetres in extent, the enormous numbers of mites found in the midst of these masses, and the attacks of the mites on face and scalp where the common itch mite does not occur. This species is apparently transmitted with great ease, and its attacks do not readily yield to treatment. Mégnin's idea that it is identical with the sarcoptes of the wolf is entirely untenable.

The case reported by Hessler apparently belongs here, though the author did not differentiate the parasite found from the ordinary itch mite. The patient was partially paralyzed and entirely helpless—hence we may infer absence of the ordinary scratching; its sequelæ are apparently entirely wanting. The body of the patient was literally covered with thick, yellowish-white, leathery scales, the largest measuring 25 mm. in diameter and nearly 3 mm. thick; these scales consisted merely of proliferated epithelial cells, and bloody or serous crusts were not present. They were, however, produced by moderate friction. In the scales on the body the author estimates the number of egg cases and eggs as seven million of which one-half to three-fourths were empty, and the number of mites as two million of which only a small fraction were living.

The following forms, normally parasitic on other hosts, may be transmitted accidentally or experimentally to man and give rise to an itch, rarely severe and usually transitory. No doubt other forms yet undescribed will fall in this same category. Besides man, only the most common host is given for each species.

S. aucheniæ. Male 0.24 by 0.18 mm.; female 0.34 by 0.26 mm. On the llama; transmitted to attendants, requiring treatment to dislodge.

S. canis. Male 0.19 to 0.23 by 0.16 to 0.18 mm.; female 0.3 to 0.45 by 0.23 to 0.35 mm. On the dog; frequently transmitted to man, variable in severity.

S. capræ. Male 0.243 by 0.188 mm.; female, 0.345 by 0.342 mm. On the goat; readily transmitted to man; induces an itch of great severity.

S. dromedarii. Male 0.29 by 0.18 mm.; female, 0.36 by 0.33 mm. On the camel; readily transmissible and severe; in Egypt almost all camel drivers are affected; the Senegal negroes call the complaint larbisch.

S. equi. Male 0.22 to 0.28 by 0.15 to 0.2 mm.; female 0.45 to 0.5 by 0.31 to 0.37 mm. On the horse; rare on man, transitory and usually disappears spontaneously.

S. leonis. Male 0.25 by 0.18 mm.; female, 0.45 by 0.35 mm. On the lion; easily transmitted to man; disappears spontaneously in thirty to forty days.

S. ovis. Male 0.22 by 0.16 mm.; female, 0.314 by 0.3 mm. On the sheep; very rarely transmitted to man, if indeed at all.

S. suis. Male 0.25 to 0.35 by 0.19 to 0.3 mm.; female 0.35 to 0.5 by 0.29 to 0.39 mm. On the pig; transmitted to man, sometimes disappears, sometimes grows worse.

S. vulpis. Male 0.245 by 0.185 mm.; female 0.442 by 0.315 mm. On the fox; its transmission to man rests on doubtful evidence.

S. wombati. Species not described in detail; forms a crustaceous itch on the wombat; readily transmitted to man; produces a type of itch intense and unlike the ordinary form; yields readily to treatment.

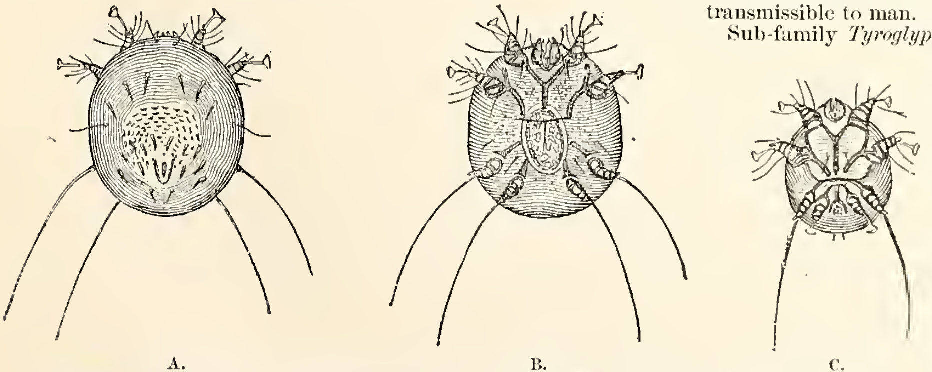

FIG. 252.—Notoedres cati: A, Female, from Above, B, from Below; C, Male. × 100. (After Railliet.)

Notoedres cati (Hering. = *Sarcoptes minor* Fürstb. Tarsal suckers with long, unjointed pedicle: in the female on the first and second pairs of legs, in the male also on the fourth. Anus dorsal, near posterior margin of abdomen. Dorsal scales obtuse. Male (Fig. 252, C) 0.14 to 0.15 by 0.12 to 0.125 mm.; female (Fig. 252, A, B) 0.21 to 0.23 by 0.16 to 0.175 mm.

This, the itch mite of the cat, attacks on its normal host the skin of the head and ears, and induces a serious, often highly epizoötic malady with a termination usually fatal. This species is of importance here because of its easy transmission to man. On the latter it produces a limited itch which disappears spontaneously at the end of from ten to twenty days. It occurs on cats in Lincoln, Nebr., and doubtless elsewhere; no cases of transmitted infection are, however, on record here.

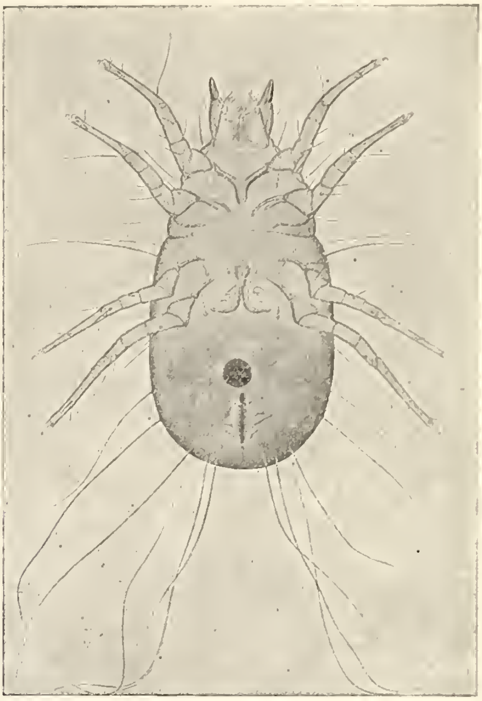

FIG. 253.—Tyroglyphus longior, Female, in Ventral Aspect. (After Mégnin.) Magnified.

The other genera and species of itch mites common to domesticated animals are not known to be transmissible to man.

Sub-family *Tyroglyphinæ* (Cheese Mites).—Minute forms with soft body, without eyes or tracheæ. Integument never uniformly striated, but smooth and granulated or irregularly verrucose. Last leg with claw and usually also with foliate, non-pedunculate vesicle.

These mites (Fig. 253) live in dry or slowly decaying materials (flour, sugar, cheese, anatomical preparations, etc.). From their minute size and abundant occurrence they are liable to be introduced on to or even into the human body, and may even make the passage of the alimentary canal without being entirely destroyed. From their presence on the body or in fecal matter under circumstances of disease they have been often reported as *corpora delicta*. In rare instances certain species have been transitory parasites of man. Where abundant, as in old groceries or warehouses, they have been known to give rise to a temporary, though often violent dermal irritation on employees handling the infected products, without the evil having been traced in all cases to any single species. Such a complaint is the "grocers' itch" of England. Since these are the most frequent pseudo-parasites with which the physician has to deal, extreme caution should be exercised in associating etiologically any species which belongs in this group with a case of disease in which it has been discovered.

Aleurobius farinæ (De Geer). (The Flour Mite)=*Tyroglyphus farinæ* Gervais. First pair of legs in male much heavier with spur on second joint. White, tip of legs pale violet. Length: male 0.33 mm., female 0.55 mm. Cosmopolitan on flour, fruit, tobacco, cheese, and other organic material in process of alteration by age. This species is much more abundant than the following even in cheese, and has frequently been described as that species in spite of evident differences. It was observed by Moniez as the cause of a cutaneous eruption on workmen unloading Russian wheat at Lille.

Tyroglyphus siro (L.) (The Cheese Mite)=*Acarus siro*, *A. lactis*, *A. dysenteriæ* L. Last pair of legs with both claw and sucker, with terminal joint short and with proximal sucker close to proximal end of terminal joint. Length 0.6 mm. Found on decomposing substances like the last, but rarer. This is the cheese mite reported by various authors from dysenteric stools and from urine. Its occurrence was undoubtedly accidental, and its harmless nature may be adjudged from the quantity taken daily in cheese everywhere and the absence in medical works of any records of consequent diseases. Yet Zürn records that in certain districts where mites are raised to impart a peculiar flavor to the cheese, a gastric or intestinal catarrh is prevalent among consumers of the cheese which he attributes to the effect of the mites. As this species is abundant in old linseed meal, its reported occurrence in poulticed wounds is easily explained. In cantharides it is also abundant, and in vanilla, where its presence has been associated with the vanilla complaint, a dermal eruption frequent among workers handling this product. The famous *Acarus dysenteriæ* of Linnæus, which was found abundantly in stools of one of his scholars and traced back to the wooden vessel from which the young man drank, was probably this species. It has, however, been reported but once since then from dysenteric stools, those of infants in Prague, and the etiological relation may certainly be called in question.

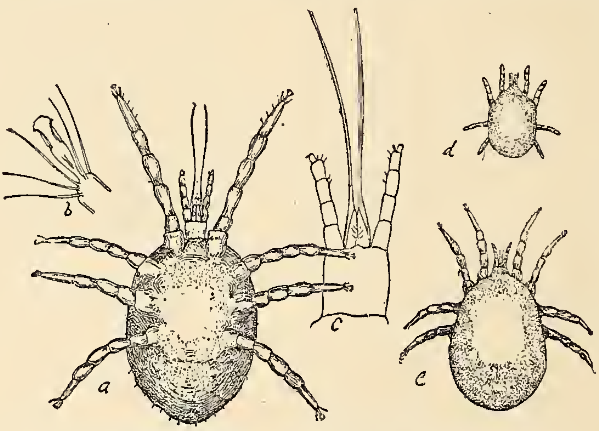

FIG. 254.—Dermanyssus gallinæ, *a*, Adult; *b*, tarsus; *c*, mouth parts; *d*, *e*, young. Magnified. (After Osborn.)

Tyroglyphus longior (Fig. 253), which is similar in habit to the last species, though less abundant, is easily distinguished by its larger size and more rapid movement. It enjoyed transient fame in 1837 as having been produced (!) by the electrical experiments of Cross on weak chemical solutions.

The mummification of bodies in caves has been shown by recent investigations of Mégnin to be due, in some cases at least, not to chemical or atmospheric influences, but to the work of *Tyroglyphus infestans*, which is abundant in such localities. The external appearance of the body and organs of the mummy was well preserved, but microscopical examination showed the tissue to be filled with incalculable myriads of the mite in all stages of development.

Gamasidæ (Beetle Mites).—Skin leathery, reinforced by chitinous plates; mandibles chelate, maxillæ filiform; six-jointed legs terminated by two somewhat concealed hooks. Stigmata lateral, between legs of second and fourth pair, with peritreme directed anteriad. Without eyes.

The Gamasidæ are abundant small mites, often free or semi-parasitic, in the latter case found on insects especially. Certain species occur on the fowl, but are often very troublesome to man. Of the large number of forms which belong in the family only two need especial mention here.

Dermanyssus gallinæ (de Geer) (The Poultry Mite). Body pyriform, slightly flattened; in the male 0.6 by 0.32 mm., in the female 0.7 to 0.75 by 0.4 mm. Color varies from white to dark red according to the contents of the alimentary canal. Legs stout, rather short. Peritreme extends as far as the base of the second pair of legs.

These mites (Fig. 254) swarm in the crevices of poultry houses and in the refuse of the floor, even living in the dung. At night they emerge from their hiding-places and suck the blood of the birds. Under circumstances they increase to such an extent as to become a veritable pest, even to man himself. Many cases are on record in which both children and adults have been subject to repeated attacks of the mites, which give rise to an itching eruption of the skin. Naturally such instances are observed among persons having to handle fowl or to resort frequently to ill-kept poultry houses. Küchenmeister, Railliet, and others record details of cases on the Continent; I have found none for this country.

Dermanyssus hirundinis (Hermann) (The Swallow Mite). Decidedly larger than the preceding, reaching a length of 1 mm. Peritreme extends barely to the third pair of legs.

This species, which normally attacks the swallow, has been known to pass from the nests under the eaves into sleeping-rooms and to attack the occupants of the room, giving rise to severe itching.

Trombidiidæ (The Harvest Mites). Soft-skinned, velvety, often highly colored mites, with tracheæ opening at the base of the rostrum or on the cephalothorax, and usually with eyes. Sucking rostrum with styliform mandibles and uncinate palpi. Legs six-jointed, terminated by a double hook together with a small sucker.

Of the large number of terrestrial mites included in this family only a few species are parasitic, but some of these, though only occasionally attacking man, are yet among his most disagreeable chance parasites. Doubtless many other species than these noted here may be found to attack him in one place or another; it is desirable that accurate data regarding all such species be on record. According to Joly and others, these mites are the passive carriers of infectious agents, but Nuttall doubts this and thinks the cutaneous affections produced by their presence on the skin are due to irritating secretions of the mites. The effect Mégnin produced by binding on the skin the dead bodies of one of the most toxic species tends to support this view. To secondary bacterial infection brought about by scratching the skin and to reduced vitality of the latter referable to the mites, are to be attributed the extreme effects manifested in the formation in some cases of ulcerous and running sores.

Pediculoides ventricosus (Newport)=*Heteropus ventricosus* Newport. Male 0.12 by 0.08 mm., oval, with six pairs of bristles and a pyriform plate on the dorsal surface. Female cylindrical, 0.2 by 0.07 mm., with four pairs of bristles. When gravid with posterior region inflated to a sphere filled with developing eggs, nearly 2 mm. in diameter, viviparous.

This form lives parasitic on insect larvæ, particularly those of grain. Numerous cases of accidental parasitism on grain shovellers, or those otherwise engaged in handling it, are reported from different parts of France and Germany. The bite of the mite produces insufferable itching and excites a considerable cutaneous inflammation.

Similar troubles have been produced by *Tarsonemus intectus* Karpelles from Bulgarian grain and *Pygmephorus uncinatus* (Flemming) from Russian wheat.

Chelytus eruditus (Schrank). Pale, rarely reddish in color, with bifid hook on the palpi. Length, 0.8 mm.

This mite occurs at times in old books or among dusty rags, but more commonly in stables, chicken or pigeon houses, in old feed bins and in tobacco storehouses, or wherever mites are abundant. In spite of its predacious habits, it has not been known to attack man, and its presence in fecal matter and in pus collected from the ear, as reported in various medical works, was undoubtedly due to accidental introduction. When St. Peter's in London was restored, this form swarmed in myriads over workmen engaged in repairing the ancient tombs.

Leptus irritans Riley. Color brick or blood red; legs terminating in two stiff hairs. Mandibles tridentate at end. Length, 0.24 mm. (Fig. 255, C). Adult unknown.

This is the larval form of some unknown, probably plant-feeding species which under temptation adopts a habit as fatal for itself as it is uncomfortable for man. Brushed from grass or shrubbery on to human clothing, it finds its way to the skin into which it burrows until entirely buried. The resultant irritation varies considerably with the individual and in some cases produces extreme torture. The inflammation gives rise to a large red blotch with paler spots and spreads rapidly when the body is scratched in consequence of the itching.

This mite occurs over much of the eastern, central, and southern portion of this country, extending in the Mississippi valley as far north as central Iowa and being very abundant in parts of Indiana, Illinois, and Ohio, even as far north as the islands in Lake Erie. In Washington it is abundant from June throughout the summer, and farther south the season is longer. Osborn speaks of the same species as annoying in Southern Mexico in January. Those who are susceptible to the pest are accustomed, on returning from field excursions, to resort at once to a hot bath with strong soap, or to the use of a wash of dilute carbolic acid to kill the mites before they become embedded in the skin. Dilute alcohol is also recommended. At this time it is also possible by close scrutiny to recognize the mites in the centre of the inflamed area and to remove them individually, doing away thus with the subsequent discomfort to a large extent.

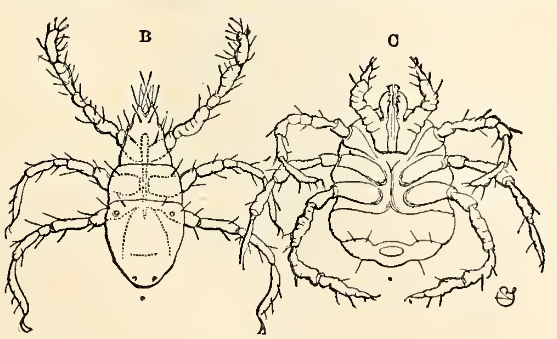

FIG. 255.—B, Leptus americanus. Greatly enlarged. (After Riley.) C, Leptus irritans. Greatly enlarged. (After Riley.) (In B and C the dots underneath indicate the natural size.)

It is interesting to note that the invasion of the human skin causes the death of the mite and prevents its reaching maturity, a perverted habit being thus fatal to the species. As a result the adult form is not known, but assumed as possibly one of the genus *Trombidium*.

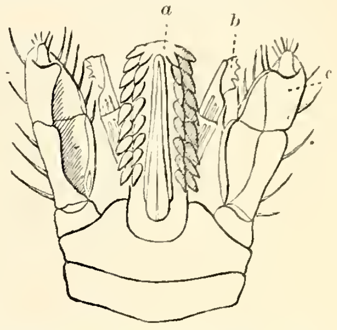

FIG. 255. — Rostrum of Ixodes hexagonus, Female, from Below. × 50 diameters. (After Delafond, from Railliet.)

Leptus americanus Riley (Fig. 255, B) is an associated form, the effects of which are very similar. The Continental species is *L. autumnalis* Shaw. Similar forms are known from all regions: among these that known as *Tlalsahuate* in Mexico, and the *Colorado* of Cuba deserve mention.

Tetranychus molestissimus Weyenberg from Uruguay and Argentine, which lives normally on an aster, is of like evil repute.

The case of *Tydeus molestus* Moniez, a blind, rose-colored mite of the family Bdellidæ or snouted mites, which was discovered on a large estate in Belgium where it first made its appearance in 1864 after an importation of Peruvian guano, illustrates the chance introduction of an undesirable species. Each year it appears at midsummer and remains until frost, so abundant that it constitutes a veritable pest. It throws itself on man passing through the grass or shrubbery and produces an insupportable itching, lasting several days.

Ixodidæ (*Ticks*).—The Ixodidæ are large mites possessing a tough leathery skin to which the six-jointed legs are attached directly. Their bodies are flattened in youth, but become more or less spherical with age. The rostrum or capitulum (Fig. 256) comprises (1) a flattened maxillolabial hypostome; (2) two elongated mandibles inflated at the base but flattened toward the tip; (3) two maxillary palpi. The lower face of hypostome and the terminal joint of the mandibles are supplied with recurved spines or hooks. The two stigmata are located near the base of the fourth pair of legs. The larva are hexapod, the nymphs octopod. The adults manifest striking sexual dimorphism.

The ticks are temporary parasites of the land-living allantoic vertebrates, among which the hosts are chosen often largely by chance. No one of them is regularly parasitic on man, but almost any of them may be upon occasion, and those species most frequently reported are so largely by virtue of their greater frequence in general or by reason of circumstances favoring their attachment in the particular instance rather than that they possess any characteristic affinity for this host.

Naturally abundant in woods and among underbrush the ticks attach themselves to such animals as pass, either reptiles, birds, or mammals. For the larvæ and nymphs this is most commonly but the means of dispersion, but with the impregnated female the parasitism becomes more definite. With the rostrum implanted in the skin and anchored by the recurved teeth, the tick gorges itself with the blood of the host until the leathery body has swollen to the size of a castor bean, which it strongly resembles. Once fully satiated the female releases her hold and falls to the ground, where she deposits her eggs and perishes. If, however, the effort be made to remove the female by force, only the greatest care prevents leaving the rostrum embedded in the flesh of the host, and at best a portion of the skin comes away with the tick.

A drop of turpentine, benzin, petroleum, or even melted butter or oil placed on the head of the tick will often succeed in causing it to loosen its hold and fall from the host. Or it may be torn or cut away, in which case the rostrum is left in the skin to be set free shortly by suppuration. It is worth mentioning that dipping is now extensively practised to free cattle from the ticks which are the means of infection in Texas fever, though the method is still in the experimental stage.

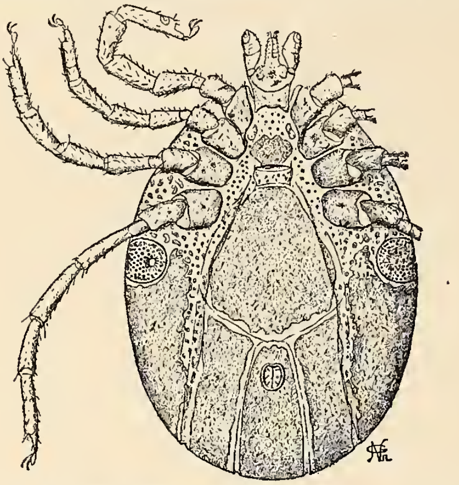
FIG. 257.—Ixodes hexagonus, Male, in Ventral Aspect. × 13. (After Neumann.)

The species which have been found upon man have not been reported with desirable accuracy. Among woodchoppers and others of similar habits, I am informed that the presence of ticks is by no means a rarity, though it rarely becomes a matter of medical record since the animal falls off or is removed by simple means in a brief time without noticeable sequelæ. In a few cases, however, dangerous symptoms manifest themselves, demanding the attention of the physician. These complications may well be due, as Railliet suggests, to the inoculation of infectious agents. Thus he says that Guadeloupe ticks carry "a sort of glanders," due to a specific microorganism, and Blanchard believes that the bacilli of anthrax and tetanus may be also transported in this way. Nuttall, however, regards the evidence as unsatisfactory.

The two sub-families Ixodinæ and Argasinæ may be distinguished easily by the position of the rostrum, which is terminal in the former and, at least in the adult, below the anterior margin of the body in the latter.

Ixodes reduvius (L.) (The Castor Bean Tick)=*I. ricinus* L. Male: brown oval, larger posteriorly, 2.5 mm. long by 1.5 mm. broad. Female: 4 mm. long and 3 mm. broad, or when gorged 10 to 11 mm. long by 6 to 7 mm. broad, ashen gray tending to brown or yellow.

The marked sexual dimorphism manifested by this species was the reason that the male and female were originally described as different species. It is common in Europe and throughout the southern United States from Maryland to Kansas and California. As host it apparently prefers sheep, goat, or beef, less often horse, dog, cat, and even man. Numerous cases of septicæmia apparently resulting from the bite of this species are recorded by European authors. In Norway emphasis is laid on the importance of not tearing off the head of a tick that has begun to bore itself into the skin. This is undoubtedly a wise precaution, and the tick may be removed without damage to the skin by the use of butter, oil, gasolene, or turpentine as mentioned above.

Ixodes hexagonus Leach (The European Dog Tick). In color, form, and size much like the preceding, this form may be distinguished by the shorter rostrum (Fig. 257) and by the tarsi which are also shorter and inflated toward the end. The male (Fig. 257) of this species is also larger, measuring 3.5 to 4 mm. by 2 to 2.5 mm.

This, the common dog tick of Europe, occurs over the entire region east of the Rocky Mountains, where it is reported from a large number of hosts. Blanchard cites cases in which it has even penetrated below the human skin.

The presence of eyes distinguishes sufficiently the genus *Amblyomma*, which includes a large number of species, from *Ixodes*, as the absence of adanal plates separates the former from *Hyalomma*, a genus not yet reported in this country; to this genus belongs the African or Senegal tick, common in tropical regions, especially of Africa, and introduced on cattle into subtropical lands adjacent thereto, where it has been frequently reported on man as the cause of intense fevers; probably the tick was only the agency in transporting the infection.

Amblyomma americanum Koch (The Lone Star Tick)=*Ixodes unipunctata* Packard. Male: body brownish-red, oval, much elongated posteriorly, 3 mm. long, 2.5 mm. broad. Female (young) colored like the male with a white spot on the back of the living animal. Length 4.5 mm., breadth 3 mm., increasing in gravid females to 8 by 12 mm. (Fig. 258).

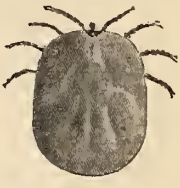
FIG. 258.—Amblyomma americanum Koch, Adult female. (Original.)

This characteristic American species occurs from Labrador to Florida and Texas and is known from South America as well. It is common on cattle in the southern part of the United States, and is reported from other domesticated as well as wild species. Packard reports a case in which a specimen had penetrated into the arm of a young girl, forming there a tumor. It is said to be very annoying to man in the warmer portions of the country, and a correspondent in Texas writes that he removed several females from his own children in one evening.

Dermacentor americanus (L.) (The American Dog Tick) =*Ixodes americanus* Gervais, *I. naponensis* and *I. albipictus* Packard. The body and margins of the legs are marked by silver-white lines and blotches. When gorged, the female measures as much as 14 mm. in length by 9 mm. in breadth.

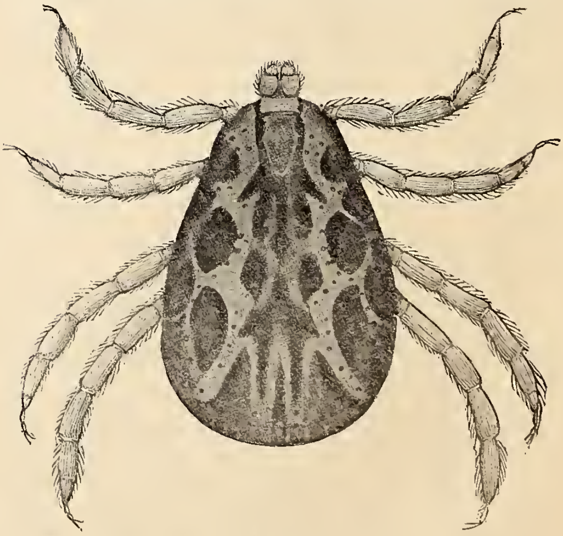
FIG. 259.—Dermacentor americanus, Dorsal view of male. × 10. (After Osborn.)

This most common dog tick (Fig. 259) is reported from almost every State in the Union as well as from Labrador, Alaska, and Mexico. The dog, cattle, and man are its most regular hosts, though a number of others are on record.

Rhipicephalus annulatus (Say)=*Ixodes bovis* Riley; *Boophilus bovis* Curtice. Female: body elliptical, slightly constricted at the middle, up to 13 mm. long by 7.5 mm. broad. Reddish-brown with two longitudinal impressions above the constriction and one below it. Rostrum very short. Male, oval, 2.15 to 2.35 mm. long by 1.3 mm. broad.

This most common of cattle ticks in the Southern States deserves mention here by virtue of its rôle in Texas-fever epidemics among cattle. It has been conclusively demonstrated that this form acts as agent in transmitting the organism which causes Texas fever, and this so-called "romance of pathology" is now an established fact. This tick is abundant south of the Maryland-Kansas line and throughout Mexico and Central America; even in Australia, Asia, and especially Africa its presence is also recorded. In Guadeloupe it goes under the name of the "Creole tick" as against the "Senegal tick" (*Hyalomma ægyptium*) previously mentioned.

Although I have found no record of the parasitism of this tick on man, a correspondent in Texas writes that it does attach itself, though rarely, to the human skin, in which situation he has seen it a half-dozen times in the last ten years. Similar occurrences, though infrequent, may be expected in regions where the species is abundant. The bite of *Hyalomma ægyptium*, the Senegal tick, may cause severe local effects in man, attributed by some to the entrance of pathogenic germs. Such results are of course most probable in tropical and sub-tropical regions, and may also at times follow the bite of this species.

The sub-family of the Argasinæ includes ticks which are parasitic on warm-blooded vertebrates, more particularly on birds, but which are frequent accidental parasites of man and occasionally the cause of serious inconvenience at least. The common European form, *Argas reflexus*, which lives in pigeon roosts but attacks also chickens and even man, is represented in this country by the following closely related species:

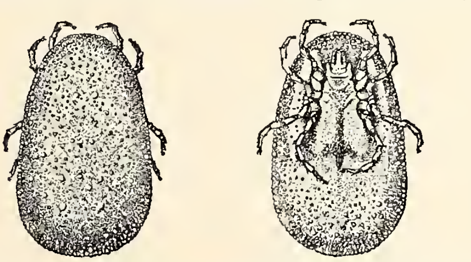

FIG. 260.—Argas americanus; Dorsal and Ventral Aspects. Enlarged. (After Marx.)

Argas americanus Packard (The Chicken Tick). Body very flat and thin, oval, 4 to 6 mm. long, 2.5 to 3.5 mm. broad, brownish-red uniformly tinted, integument pitted, with the pits larger near the middle, becoming smaller toward the edges.

This tick (Fig. 260) attacks especially chickens and turkeys. It is probably the "Argas chinche," said by Goudot to be abundant in Colombia and to resemble the bedbug in habits as in appearance; there it torments especially the human species. It lives in the chinks of woodwork and walls, from which it sallies forth at night to feast on the blood of some convenient host. These mites are very hardy and have been known to live in abandoned dove cotes from eight to forty-eight months without food. The bite of the European form (*A. reflexus*) undoubtedly causes serious consequences at times, chiefly in the case of infants and children, or of individuals highly susceptible to urticaria factitia, causing œdema of the part or even of the entire body, together with intense pruritus lasting several days. For a record of the cases and details see Brandes. Records of the American species are scanty, but it is said to attack sleeping men and animals, producing in the former dermal irritation of a grave character.

The *Argas persicus*, or Miana bug, is an Eastern species of some reputation which is said to molest travellers in Persia, and the bite is believed to be accompanied at times by serious consequences. The general report, according to which the bite of these ticks is especially dangerous during the hot months, may find its justification in the transmission by this means of some tropical disease germ, as has been demonstrated in the case of Texas fever. The acute symptoms which may be manifested at any season are believed to be due to a poisonous saliva, and the experiment of Mégnin on a specimen kept in confinement for four years certainly does not demonstrate the harmless character of the tick. "Bacteria may of course gain access to the wounds inflicted, which are possibly more prone to infection in consequence of the injurious influences of the secretions of the Argas. Depending on the character of the organisms introduced, the later symptoms will naturally vary" (Nuttall). *Argas sanchezi* of California and Mexico, which is very closely related to *A. persicus*, does not enjoy a similar reputation.

Ornithodoros turicata, found in the Gulf States and in Mexico, and *O. talaje* of Central and South America, are forms not well known, which encroach upon our southern borders. The first is parasitic upon the pig and man. Its bite is painful and may produce dangerous symptoms.

Henry B. Ward.

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ARAGON, BATHS OF.—These baths are located in the Aragon Hacienda, municipality of Guadalupe Hidalgo. The situation is 4 km. from the Guadalupe Hidalgo and is accessible by the electric railway line between Mexico and Guadalupe.

According to an analysis by Prof. G. Mendoza the water is composed as follows:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Iron bicarbonate	3.82
Sodium bicarbonate	3.42
Potassium bicarbonate	0.37
Calcium bicarbonate	0.15
Magnesium bicarbonate	0.16
Sodium chloride	0.38
Silica	5.68
Free chromic acid (?)	4.52
Total	18.50

The water is heavily charged with carbonic-acid gas. It has a temperature of 77° F. and a density of 1.021. It may be classified as a carbonated chalybeate water, and possesses strong tonic properties. It has been found very useful in anæmia, chlorosis, and kindred disorders.

N. J. Ponce de Léon.

ARALIACEÆ.—(*The Ivy Family.*) A family of some forty genera and about four hundred species, widely distributed through temperate and tropical regions of both the old and the new worlds. Its plants are highly ornamental, some, like the ivy, being extensively cultivated for this purpose. Medicinally, it is of note as yielding the famous ginsing. Its constituents are simply aromatic and without special properties. The spikenard, and several other species of aralia, were formerly very extensively used, and are still used to a considerable extent, for these properties. Some of them contain amaroids in connection with their resins and volatile oils.

H. H. Rusby.

ARBOR VITÆ.—(*Thuja.* The fresh tops of *Thuja occidentalis* L., Fam. *Coniferæ.*) This is a North American tree, growing abundantly in Canada and the Northern States, and extending at higher elevations as far south as Pennsylvania and Virginia. It is a middling or good-sized evergreen tree with spreading and graceful branches, and a fine, often large, trunk, which supplies a close-grained, durable wood. It is occasionally planted here for ornament, but more often abroad, where it is valued as a garden tree; the *Arbor vitæ* of our gardens is usually the smaller, closer, erect-branching *Thuja orientalis* Linn. of Asia, which is a favorite hedge plant. The genus to which these belong is a small one of only a dozen species.

The twigs were thus described in the Pharmacopœia, edition of 1880: "Twigs flattish, two-edged, the scale like leaves appressed and closely imbricate in four rows, rhombic-ovate, obtusely pointed, with a roundish gland upon the back; of a balsamic, somewhat terebinthinate odor, and a pungently aromatic, camphoraceous, and bitter taste."

Arbor vitæ contains about one per cent. of a *volatile oil,* something like that of juniper; *tannic acid* (pinitannic); a minute amount of a glucoside called *thujin,* etc.

Medical Properties.—Astringent, diuretic, expectorant, tonic, etc., in no direction of much value. Sometimes used for cough; a tincture is employed occasionally for external use upon ulcers, rheumatic joints, etc. Dose, 2 to 4 gm. An alcoholic fluid extract would be a suitable preparation. *W. P. Bolles.*

ARCACHON.—The town of Arcachon lies about thirty miles southwest of Bordeaux, on the margin of a very extensive salt-water lake, and some ten miles back from the Atlantic coast. The modern origin of the town is indicated by the motto inscribed upon its coat-of-arms, *Heri solitudo, hodie pagus, cras civitas;* which motto is also an indication of the former character of the surrounding country. A desert waste of barren sand dunes extended for many miles in every direction about the present site of Arcachon, until the French Government, some fifty years ago, conceived the project of planting these dunes with pine forests, as a means of immobilizing the sand which, driven by the fury of the Atlantic gales, was continually encroaching more and more upon the country of the interior. A thick forest of these trees (Pinus maritima) now covers the whole face of the country, and by these pine-covered sand hills the site selected (in 1854) for the now well-known sea-coast resort of Arcachon is shut in and protected on every side except upon the north, which is occupied by the great salt-water lake above mentioned, upon whose southern shore the town is built.

[There are nine thousand acres of these pine trees, which produce a most peculiar stillness—owing to the deep sand roads and walks not giving any sound, and the pine trees having no leaves to rustle.—*E. O. O.*]

From its close proximity to the Atlantic Ocean, Arcachon necessarily possesses a climate characterized by the moderate moisture of atmosphere, and by the equability of temperature proper to most maritime stations. The direction of the prevailing winds, which in this region blow from the ocean, is an important factor insuring to this sea-coast station its proper maritime climate. From the direct violence of the Atlantic gales, as well as from the winds blowing from the east and south, Arcachon is sheltered by the dense pine forest which clothes the surrounding sand dunes; while the sandy nature of its soil serves in some measure to diminish the tendency to excessive atmospheric humidity which might, perhaps, be expected to exist in a region thus exposed to ocean winds.

Winds blowing from the north and from the northeast reach Arcachon after passing over its great lake or land-locked bay, the circumference of which is stated by Dr. J. H. Bennet to be sixty-eight miles in length. Such north and northeast winds, therefore, "become somewhat warmed in winter, and their irritating dryness diminished, while it is maintained that they also bring from the surface of this unusually salt sea water, and from the vast extent of sands exposed by the retreating tides, an appreciable amount of saline and other marine emanations, to give a special efficacy to the air in certain scrofulous conditions" ("Health Resorts and Their Uses," by J. Burney Yeo, M.D., p. 261). According to the author just quoted, the prevailing winds at Arcachon, namely, the sea winds blowing from the northwest, west, and southwest, occur most frequently from December to February, "usually blow continuously day and night for several days in succession . . . often blow with great violence, and were it not for the protection of the lofty pine-trees . . . would form a serious drawback to the climate." The average number of rainy days in that portion of France in which Arcachon is situated is stated by Lombard to be one hundred and thirty, while the total amount of the annual rainfall is twenty-three inches, a greater part of which falls during the winter and autumn months than during the spring and summer seasons

The mean temperature for the year at Arcachon is 59° F.; the mean temperature of the winter season 46.4° F. to 50° F. (Lombard). At Bordeaux the mean winter temperature (according to the same author) is 43.7° F., and the mean annual temperature is 55.6°. A very pronounced difference of temperature between these two points is thus made manifest despite the trifling difference in latitude existing between them. According to data quoted from Dr. G. Hameau in the "Dictionnaire Usuel des Sciences Médicales," the result of a series of thermometric observations taken in the pine woods at Arcachon, and covering a period of ten years, showed the mean annual temperature at 8 A.M. to be 55.76° F., and at noon to be 59.96° F.; for the minimum temperatures the annual mean was found to be 46.94° F.; for the maximum temperatures it was 66.2° F.

Arcachon is both a summer and a winter resort, and there are two distinct portions of the town, the one, adapted for residence during the warmer months, lying directly on the shore of the salt-water lake or basin, and possessing facilities for bathing; the other lying away from the water in the midst of the pine forest, separated from the shore town by a high sand dune, and consisting of "numerous villa residences actually built in the forest, each house being surrounded by pine trees" (Dr. J. Burney Yeo, *op. cit.*). This latter section is known as the Ville d'Hiver, or winter town, while the former is called the Plage, or beach. Of this Plage, Dr. Yeo remarks that it is "occupied by somewhat closely packed streets and houses," and becomes in summer time "a sort of Margate for the population of Bordeaux." Dr. J. H. Bennet says of Arcachon that it is "a pretty sea-side town . . . with good hotels, picturesque villas, convenient and handsome club house and baths—indeed, all the appurtenances of advanced civilization. The summer town is built on the sandy shore of the great lake or sea, which affords excellent bathing. The lake itself, from its great extent and from its being landlocked on every side, offers every possible facility for safe boating, yachting, and fishing." After describing the Ville d'Hiver and giving much other interesting information concerning Arcachon in his entertaining book, "Winter

Cestodes.

may happen, there be no benefit for the first two or three days; and especially should doses be given on the empty stomach early in the morning and late at night.*

Edward Curtis.

CERVICAL FISTULA. See *Teratology.*

CERVICO-BRACHIAL NEURALGIA. See *Neuralgia.*

CERVICO-OCCIPITAL NEURALGIA. See *Neuralgia.*

CESTODA.†—The branch or Phylum Platyhelminthes, commonly known as the Flat Worms, is characterized by a bilaterally symmetrical body somewhat flattened dorso-ventrally and usually elongate, by the mass of parenchymatous tissue which fills all the spaces of the body, by the absence of any true body cavity, by a protonephridial excretory system, and by the complicated sexual apparatus which with rare exceptions is hermaphroditic, and which produces so called compound eggs. Among the most prominent orders of the branch are the Trematoda or Flukes (*q. v.*) and the Cestoda or Tapeworms to be considered here.

The order Cestoda includes a large number of forms which manifest considerable differences in anatomical detail, but are comparatively uniform in general appearance and structure. The small group of Cestodaria, or Monozoa, which differ from all others in possessing but a single set of reproductive organs, and consequently but a single segment in the body, is included by some investigators in the order under consideration, but by others placed intermediate between the trematodes and the cestodes, forming as it undoubtedly does a group transitional from the one order to the other. The species of Cestodaria are, however, rare and infest the lower animals, so that they will not be discussed here.

In the Cestoda *s. str.* the body is characteristically ribbon-like and divided into "links," segments, or proglottides. In most cases, including all the tapeworms of man, the segmentation is evident externally. At the posterior end of the chain the proglottides are larger and more distinct, and often so loosely attached as to separate from the series under the slightest disturbance. In fact such separation takes place normally as the segments become ripe. Toward the other end of the chain the proglottides grow gradually smaller and less distinct until near the anterior end it is usual to find a short region, the neck, in which no trace of segmentation is visible. The anterior end has the form of a bulbous swelling, known as the head or scolex (Fig. 1203), on which are borne the organs of fixation. The latter are either suckers, hooks, or both, and the suckers may be either elongate grooves or bothridia, cup-shaped hollows or acetabula, or, as in some marine tapeworms, of a folded form which is much more complicated.

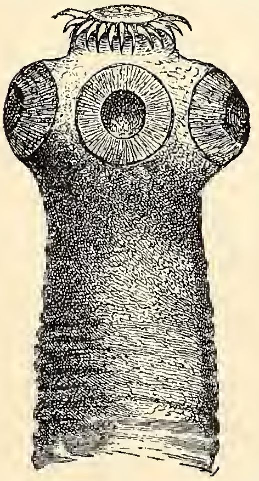

FIG. 1203.—Anterior End of *Tænia solium*, Showing Scolex, Suckers, Rostellum with Hooks, and Neck. × 45.

At the apex of the head is found in the Tæniadæ a muscular organ, the rostellum which bears the hooks, usually in one or more annular rows. In form and degree of development the rostellum is a very variable organ; at the one extreme in *Tænia saginata* it is reduced to a small muscular sucking apparatus, often spoken of as the apical or fifth sucker of that species, while in other forms it is powerfully developed and capable of extension or retraction into a pocket at the apex of the scolex. It is a valuable feature in the distinction of various species.

In the head one finds the central nervous system in the form of a bilateral ganglionic mass with one or two ring-like commissures from which nerves are given off directly to the suckers and rostellum, and from which the longitudinal nerve trunks pass backward throughout the length of the chain. Three of these trunks, the main lateral nerve (Fig. 1204, *ln*) and two minor (*ln'*) are grouped together on each side of the proglottis, while the two dorsal and the two ventral longitudinal nerves (*ln"*) are located nearer the median line. The various longitudinal trunks are connected by commissures which at stated intervals pass around the proglottis; they also give off branches by which the various organs are innervated.

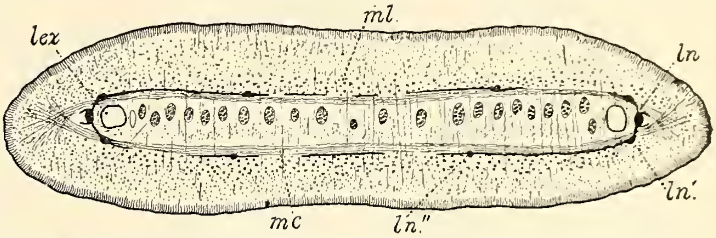

FIG. 1204.—Transection of Proglottis of *Tænia solium*, Somewhat Diagrammatic. *ln*, Main lateral nerve; *ln'*, accessory lateral nerve; *ln"*, ventral longitudinal nerve; *lex*, longitudinal excretory canal; *ml*, longitudinal body muscles; *mc*, transverse body muscles. The section is represented as having cut one of the ring commissures throughout nearly its entire extent. (Original.)

Near the lateral nerve trunks are located the main longitudinal canals (*lex*) of the excretory system which originate in an irregular network in the head and from which are given off numerous branches often in the form of a network of fine vessels in each proglottis. In many forms a prominent transverse canal near the posterior margin of each proglottis joins the longitudinal canals (*cf.* Fig. 1205, *C*). Terminating the finer canals of this system are found the characteristic flame cells which are peculiar to this type of excretory system.

A cross section of a proglottis (Fig. 1204) shows the various layers of which it is composed. Externally the cuticula, a resistant, elastic membrane, covers the body and is reflected a short distance inward at the various external orifices. The older view, by virtue of which an epithelium is wanting in cestodes and the outer layer represents a basement membrane, has been definitely set aside by the recent investigations of Blochmann; the cuticula is really the product of the subcuticular cells, though they are apparently separated from it by a considerable interval. Immediately beneath it occurs a delicate double layer of dermal muscles, having externally circular, and internally longitudinal fibres, the myoblasts of which lie deeper in the body. Between these fibres the bases of the subcuticular cells extend from the cuticula to the deeper lying bodies of the cells; the remaining space of the body between the various organs is filled with parenchymatous tissue. Within the parenchyma occur usually large numbers of calcareous bodies, highly refractive spherical or oval masses of small size, the function of which is yet uncertain. They are, however, characteristic features of cestode structure.

The cross section is divided by the parenchyme or body musculature into two regions, an external cortical layer and the median area or medullary region. In the latter are found most of the reproductive organs, although in the Bothriocephalidæ the vitellaria lie in the cortical layer. The body muscles are of three sets, longitudinal, transverse, and dorso-ventral or sagittal. The longitudinal muscles (Fig. 1204, *ml*) form the outer layer of the muscular mass broken only at the sexual pore, and though variable in amount are always numerous. The transverse muscles (*mc*), often called circular, constitute a plate just within the longitudinal fibres; at the side these fibres intersect and spread through the longitudinal muscles like the rays of a fan. The sagittal fibres extend singly or in small bundles from dorsal to ventral surfaces directly through the proglottid; they are scattered and not so numerous as the other systems of fibres.

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* Report to New York Therapeutical Society; the Medical Record, June 12th, 1880.

† A general discussion of parasitism and its effects will be found under the heading *Parasites.*

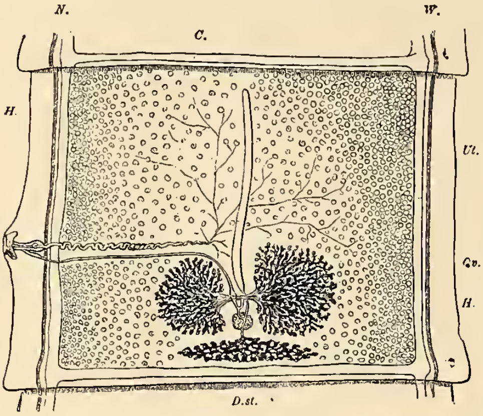

FIG. 1205.—Sexually Mature Proglottis of *Tœnia saginata*. *C*, Transverse commissure of excretory canals; *Cl*, genital cloaca; *D.st.*, vitellarium; *H*, testicular follicles; *N*, lateral nerve trunk; *Ov*, ovary; *Ut*, uterus; *W*, longitudinal excretory canal. × 10.

Absolutely no trace of an alimentary tract has yet been discovered in the cestodes. Imbibition is the only known method of taking food, and the adult tapeworms are accordingly limited to those organs, alimentary canal and serous cavities, in which the parasite is bathed in a nutrient fluid.

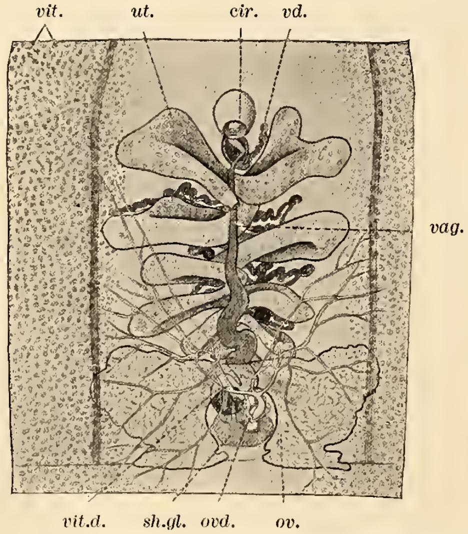

FIG. 1206.—Central Portion of the Sexually Mature Proglottis of *Dibothriocephalus latus* from the Ventral Surface. *cir*, Cirrus sac; *ov.*, ovary; *ovd.*, oviduct; *sh.gl.*, shell gland; *ut.*, loop of uterus; *vag.*, vagina; *vd.*, coil of dorsal vas deferens; *vit.*, vitellaria; *vit.d.*, yolk duct. The numerous follicular testes lie beneath, *i.e.*, dorsal to the vitellaria shown here. (After Sommer and Landois.)

The organs of the reproductive system are grouped so that each proglottis contains a complete set, and even when the body is not segmented externally, examination of the internal structure shows them to be repeated. Each proglottis contains all the organs of both sexes (Fig. 1209) and appears in this respect a complete hermaphroditic individual. The organs first make their appearance in the anterior proglottides as indistinct cords of cells which gradually assume the character of the sexually mature condition. In general the male organs reach maturity a little in advance of the female, and copulation with an older proglottis of the same or of a different chain may hence be inferred. The male system consist of numerous small testes, the vasa efferentia of which unite near the centre of the segment to a common vas deferens, and the latter, which is commonly provided with an enlargement, the vesicula seminalis, and which terminates in a copulatory organ, the cirrus, opens with the vagina into a genital cloaca (*cl*) at the common genital pore, located either at the margin or on the surface of the segment. The female organs may be said to take their origin from the genital pore with the vagina which leads inward, furnished at some point with an enlargement, the receptaculum seminis, in which the supply of sperm is stored up. The ovary, either single or paired, empties by an oviduct which joins the vagina near the shell gland and which often has near its origin a muscular organ, the oocapt, by which the eggs are taken from the ovary and forced onward to the vagina. The vitellarium is a single, large racemose gland (*D.st.*, Fig. 1205), or a multitude of small follicles (*vit.*, Fig. 1206) in which are produced the masses of yolk material to be included in the eggs. Vitelline duct and oviduct join the continuation of the vaginal canal in the shell gland, and to this portion of the duct the name ootype has been given. Here the ovum coming from the ovary is fertilized by the spermatazoon from the seminal receptacle, is surrounded by a mass of yolk material from the vitellarium, and the whole encased in a capsule formed by the secretion of the shell gland, which rapidly hardens into a thick chitinous shell. The completed eggs are then forced onward into the uterus. Since they consist not only of a fertilized ovum but also of a mass of disintegrated yolk cells, the name compound egg has been applied to them. Such eggs occur only in the flat worms.

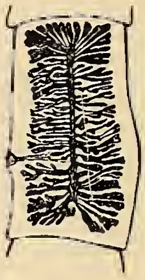

FIG. 1207.—Ripe Proglottis of *Tœnia saginata* with branched uterus. × 2. (After Braun.)

The uterus may possess a special external opening or may be without such. In the latter case it is small at first, but with the accumulation of eggs it becomes irregularly enlarged by the formation of lateral outpocketings so as to occupy with its branches almost the entire space of the proglottis (Fig. 1207). In the course of this transformation other organs gradually disappear until the ripe segment is little more than a muscular sac which encloses the branching uterus crowded with eggs. The manner of branching is characteristic of the species, as is also the way in which ripe proglottides are detached either singly or in groups, and both features together with other details in the structure of the reproductive system are discussed in connection with the individual species.

The eggs of the cestodes are oval and provided with a thin shell which is often supplied with a lid. Within this occurs in many eggs (Fig. 1208) a thicker second shell, so-called, of a structure characteristic for the family in which it occurs. In reality this inner structure is not a shell but an embryonic membrane, and takes its origin during the early growth of the germ cell, which occurs in most cases while the egg is still retained in the uterus of the adult cestode. When the uterine egg is examined soon after its formation, the shell is seen to contain a single germ cell surrounded by a number of yolk cells which, in some cases, have lost their cellular identity and constitute merely a mass of granular yolk substance.

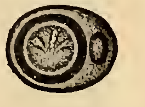

FIG. 1208.—Egg of *Tœnia solium*. × 380. (After Leuckart.)

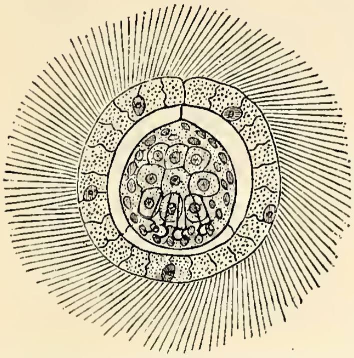

FIG. 1209.—Free Swimming Onchosphere of *Dibothriocephalus latus* in ciliated mantle. × 500. (After Schauinsland.)

The embryo originates from the development of the egg cell alone while the yolk cells serve as nutriment during its early growth. From the division of the egg cell, which undergoes total cleavage, there arises a spherical embryo surrounded by one or more embryonic membranes. From the latter may originate an inner shell, as is the case in Tæniadæ (Fig. 1208), or a ciliated mantle, as in Bothriocephalidæ (Fig. 1209). The spherical embryo (Fig. 1210), which is known as the onchosphere, is uniformly characterized by the presence of three pairs of hooks of variable shape and by great mobility, and in this condition is ready for introduction into the secondary host. This may be the result of a direct migration, as when the ciliated bothriocephalid embryo, swimming about in the water, is swallowed by a suitable host; or it may be of passive character, as when the tænioid egg containing an embryo enveloped in its membranes arrives by chance in the alimentary canal of the larval host; in the latter case, at least, it is necessary that the eggs should be introduced into the stomach and be subjected to the action of the gastric juice to disintegrate the shell and membrane. Were this not so it is clear that the harboring of the adult in the intestine would be, in those cases in which the larva parasitizes in the same animal, a source of extensive secondary infection. In such cases it is well known, as for instance in *Tænia solium* of man, that any reversal of the ordinary peristaltic action of the canal, which brings loose proglottides into the stomach and subjects them to gastric digestion, will result in the release of the six-hooked onchospheres, and in the infection of the host with the larvæ. Once that the membranes are broken down and the onchospheres set free they bore their way actively, by virtue of the hooks, through the wall, probably in most cases of the proximal portion of the intestine, and are believed to be distributed further by virtue of the portal circulation; at least the liver and the connective tissue adjacent to it are the chief seats of the larvæ. Having come to rest at such a point the embryo throws off its hooks and forms on its surface a thick cuticular layer beneath which are differentiated the muscle fibres, while about each embryo is formed a cyst by the activity of the host. The centre of the sphere is filled at first with a loose parenchymatous tissue in which soon appear irregular spaces that later fuse to form a large central cavity. Thus has been reached the first form of the larval stage known as the bladder worm or cysticercus (Fig. 1211). A growth of two to four weeks is sufficient in most cases to bring the cysticercus to the diameter of a millimeter, when the second stage in the development is entered upon by the appearance of a meniscoid proliferation of cells at some point on the bladder; into this projection there penetrates from the exterior a hollow cylindrical ingrowth of the cuticula (Fig. 1211) forming the starting-point of the scolex of the adult worm. As the growth becomes larger the ingrowth presents the form of a flask (Fig. 1212, *A*); it is still covered throughout by a cuticular layer, and at the base of the flask there arise in reverse the structures which characterize the head of the tapeworm: at the centre the rostellum with its crown of hooks, and on the sides the suckers having, when fully developed, the characteristic form and size (Fig. 1212, *B*) of the adult.

FIG. 1210.—Free Onchosphere, Magnified.

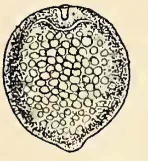

FIG. 1211.—Young Cysticercus of *Tænia saginata* with beginning of Scolex Ingrowth, Seen in Optical Section. Magnified. (After Leuckart.)

Under proper conditions the head begins to be everted, starting from the base and continuing until, with the neck, it ultimately projects above the surface of the bladder (Fig. 1213). This process may at times take place while the bladder worm is still retained within its host. In other instances the consumption of the flesh in which the cysticercus is enclosed and the digestion of the surrounding tissue form the stimulus for the evagination of the scolex. It is interesting to note that under the influence of the alimentary secretions of the definite host the bladder of the cysticercus is entirely digested, its remnant appearing as a ragged fringe (Fig. 1214, A), at the base of the fully extended scolex and neck. Having attached itself the scolex enters upon a period of rapid increase in length, which is soon accompanied by the appearance of the first proglottides (Fig. 1214, B). The scolex system of excretory canals originates early (Fig. 1208) even before the suckers and rostellum have appeared, and persist unchanged in the scolex of the fully developed adult.

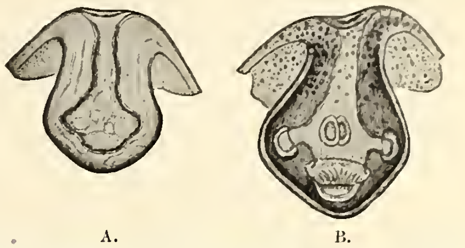

FIG. 1212.—Formation of Scolex in Reverse on Cysticercus of *Tænia serrata*. A, Early stage; B, fully developed scolex. Magnified. (After Leuckart.)

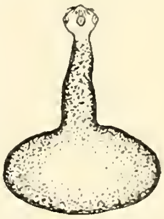

FIG. 1213.—Cysticercus of *Tænia serrata* with Everted Scolex. (After Leuckart.)

In the formation of the proglottides it may be noted that the terminal proglottis is the oldest, and that new segments are continually formed in the vicinity of the neck. The sexual organs appear early as strings or masses of embryonic cells in the midst of the parenchyma. Formation of proglottides and growth proceed so rapidly that the tapeworm has matured and set free the posterior joints in a brief period. These reach the exterior with the fæcal matter, often manifesting great independence and power in movement. They contain masses of eggs stored up in the uterus with which the beginning of the life cycle is again reached.

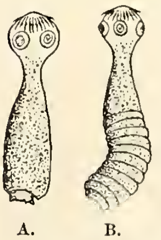

FIG. 1214.—Young *Tænia serrata*. A, Immediately after digestion of bladder by new host; B, with a few proglottides. (After Leuckart.)

The normal seat of the tapeworm is in the alimentary canal, and usually in the small intestine, where the worm lies close to the wall with its head more or less embedded in the villi. Occasionally one of the smaller species wanders from this place into the ductus choledochus, and more rarely into the liver itself. This seems to be the normal habit of a few species not found in man. The occurrence of tapeworms in the human stomach or anterior thereto, as reported by various medical observers, is due either to a postmortem wandering or to regurgitation. On the other hand the reported occurrence of Cestoda in the bladder, and the discharge of proglottides from the urethra, can be explained, in so far as the cases do not rest on erroneous observations, only on the basis of injury or accidental introduction. Portions of a tapeworm have been at times discharged from abscesses or fistulæ which have probably had at some time a connection with the intestine. Leidy's discovery of a specimen in a cucumber admits, however, of no such natural explanation. Though often torpid when examined after discharge, the tapeworm is undoubtedly, it must be remembered, active in its warm-blooded host. To its contractions are due the serious symptoms which often accompany its presence. Even the discharged proglottides live for several days outside the host under ordinary circumstances and perform migrations and movements of considerable extent. By virtue of this apparent completeness and activity, the separate proglottides are frequently diagnosed as flukes.

The effect of the parasite on its host may be regarded first from the standpoint of loss of nutriment. This has been carefully computed by Leuckart for the largest human tapeworms, and amounts in one year for a single specimen of *Dibothriocephalus latus* to from 500 to 700 gm., and for *Tænia saginata* to from 1,500 to 2,000 gm. Although the presence of a number of individuals may heighten this materially, yet the amount is entirely inadequate to explain the far-reaching effects which are manifested by man as the result of the presence of only a single one of these parasites. The severe symptoms are noticeably of a nervous character. Anæmia is a frequent manifestation, and this displays at times a pernicious tendency which in one case at least has terminated fatally.

Many of the symptoms affecting individuals who harbor tapeworms have been attributed to poisons developed by the parasite within the body of the host. Not only is this evinced by the subsidence of the nervous and epileptic symptoms on the removal of the tapeworms, but the affections of the eyes so frequent in those afflicted may naturally be due to the effects of a poison absorbed from the intestine and circulating in the blood. The fluid extracted from a hydatid cyst has been shown by experiment on man and animals to be toxic. To this quality may doubtless be attributed the severe symptoms or even death consequent upon the rupture of such a cyst or its operative puncture. An extract from *Dibothriocephalus latus* has been shown to exert a globulicidal effect on dogs, and one of *Tænia saginata* has been found to kill tubercle bacilli.

The symptoms of tapeworm disease are by no means well defined and may include almost any possible combination. In experimenting upon himself, however, Stiles noted during the presence of *Tænia saginata* as the most constant symptom one not heretofore recorded. He says: "During the time of infection it would very frequently happen as I walked along the street or across the room that I suddenly felt a peculiar sensation almost exactly similar to the sensation one feels upon the sudden descent of an elevator." Despite the indefiniteness of the clinical aspect of tapeworm infection, any suspicions of such trouble may be definitely tested by a microscopical investigation of the fæces. The presence of adult cestodes will be manifested by an abundance of their characteristic eggs.

The specifics which are most frequently employed in driving out tapeworms are Cortex granati, of which the effective principle is an alkaloid known as "pelletierine," Flores Kouso containing the amorphous kosotoxin, Rhizoma filicis containing the amorphous filicic acid, and kamala with the resinous kamalin (see *Anthelminthics*). In bringing about the evacuation of the parasite some precautions are necessary to insure success. When a patient is passing a tapeworm the parasite sometimes breaks in two owing to the transition from the warm bowels to the cold air or to a cold porcelain vessel. By the use of a vessel containing warm water this sudden change and its consequent evil effects may be avoided. In the next place cestodes are frequently expelled in a knotted mass, and any obstruction in the lower portion of the canal may delay their passage sufficiently to permit the parasite to secure a new hold on the wall. Consequently success may depend upon thoroughly clearing out the canal.

The distribution of each species will be considered under its proper heading; here, however, some general items may be noted concerning the frequence of tapeworms. Stiles gives the following table of:

CASES OF TAPEWORM IN MAN.

Authority.	Total number of cases reported.	SEX OF PATIENTS.	
		Male.	Female.
Wawruck	173	56	117
Crisp	247	96	151
Seeger	26	10	16
Monti	240*	111	129
Roger	10*	3	7
Krabbe	367	126	241
Total	1,063	402	661

* Children.

He attributes the evident sex difference merely to the fact that women ordinarily prepare the food, and are hence more exposed to chance infection than men. Statistics of French maritime hospitals give for the period 1886–90 about 1.5 per cent. of cases for tapeworm infection, and records of the United States hospital service during the war contain a total of only .012 per cent. treated for tapeworms. This percentage is under the circumstances naturally abnormally low as compared with conditions in times of peace.

The occurrence of various species in different regions may be adjudged from the following table. Such figures exist only for a very few localities:

Authority.	Country.	Dates of records.	Total number of cases.	Tænia saginata.	Tænia solium.	Diboth. latus.	Dipyl. caninum.	Hymen. diminuta.	Indet.
Parona	Milan	1899	150	121	11	4	..	..	14
Parona	Italy	1868–99	513	397	71	26	..	..	19
Krabbe	Denmark.	1869	100	37	53	9	1	..	..
Krabbe	Denmark.	1869–87	200	153	24	16	8	..	..
Krabbe	Denmark.	1887–95	100	89	....	5	6	..	..
Stiles	U. S. A.	1897	....	Many	Rare	3	..	1	..

Cestodes have been known from the earliest times, and both tapeworms and bladder worms are distinctly recognized in the oldest medical works which have come down to us. One of the hermetic books of the Egyptians, that on medicaments now known as the Papyros Ebers, and dated about 1550 B.C., gives in hieratic writing extensive sections on these parasites and their treatment, which are taken in part from the writings of earlier physicians. The proscription placed by Moses on the use of certain flesh has its undoubted ground in the abundant presence in such animals of bladder worms. Hippocrates notes the presence of echinococcus bladders in man and an operative method for removing them. He also speaks of the evacuation of fragments like pumpkin seeds as diagnostic of the tapeworm. Both he and Aristotle speak of the bladder worm of the pig as well known, and advise the detection of its presence by examining the lower surface of the pig's tongue where the cysticerci appear as swellings. This method is followed even to-day. Aristotle showed also that the tapeworm in contrast with the free round worms of the intestine was attached to the wall of the canal. Pliny adds to the accounts of his predecessors which he quotes only fabulous reports of the length of tapeworms (up to three hundred feet!) and erroneous observations on their presence in cold springs. Galen mentions bladder worms from the abdomen of slaughtered animals and notes the tendency of the liver to "produce" these forms in its surrounding fascia.

It was 1600 A.D., however, before even two species were differentiated among human tapeworms, and 1700

A.D. before the tapeworm head was recognized. About this time cestodes from other hosts began to be studied and the animal nature of the bladder worms, which had previously been regarded as tumors or concretions, was successfully maintained. Even then authors noted the resemblance of certain cestodes and cysticerci, and in 1782 Goeze united the two groups, but this procedure was not accepted by later authors for more than half a century.

The origin of these parasites was universally attributed to spontaneous generation, the tapeworm being said to originate from the inner wall of the canal, from surplus food of a thick character like milk or cheese, or from febrile mucous secretions, while the cysticerci were generally regarded as tumors (hydatids). This belief lasted long, even after the discovery of the eggs in many species. Linnæus was responsible for propagating another serious error, that the cestodes were free living as well as parasitic; and this was not finally refuted until the end of the eighteenth century. It was Zeder who in 1800 first divided the parasitic worms into five classes to which Rudolphi in 1804 gave the Greek names, Nematoidea, Acanthocephala, Trematoda, Cestoidea, Cystica, which they still bear. Of the last two, the tapeworms and bladder worms, Küchenmeister was able to prove about the middle of the century by feeding experiments that the latter were only developmental stages of the former, thus incorporating both in the group of cestodes. Among these those forms with only a single segment may be distinguished as the Cestodaria from the Cestoda *s. str.*, in which group are included the large majority of the tapeworms, and all of the forms reported from man. The latter may be arranged according to the following scheme which adopts the system proposed by Braun. The groups omitted here contain no forms recorded as human parasites. Annotation is made of the stage in which each species is a human parasite and of those forms thus far recorded in this country;

Order Cyclophyllidea.		
Family Tæniadæ.		
Tænia saginata.	Adult in man.	U. S. A.
" africana.	" "	
" solium.	" "	U. S. A.
" confusa.	" "	U. S. A.
" serrata.	Larva in man (?)	
" marginata.	" " (?)	U. S. A.
" echinococcus.	" "	U. S. A.
Davainea madagascariensis.	Adult in man.	
Hymenolepis nana.	" "	U. S. A.
" diminuta.	" "	U. S. A. (?)
Dipylidium caninum.	" "	
Order Pseudophyllidea.		
Family Bothriocephalidæ.		
Dibothriocephalus latus.	Adult in man.	U. S. A. (?)
" cordatus.	" "	
Dibothrium Mansoni.	Larva in man.	
Diplogonoporus grandis.	Adult "	

KEY TO ADULT TAPEWORMS OF MAN.

Scolex with four circular suckers; proglottides with marginal genital pore and without uterine orifice.
Cyclophyllidea—Tæniadæ. (A.)

Scolex with two longitudinal sucking grooves; proglottides with superficial genital pore and with special uterine orifice.
Pseudophyllidea—Bothriocephalidæ. (B.)

(A.) Large forms; uterus in ripe proglottides with median longitudinal trunk and numerous lateral branches; eggs with thin outer and thick inner shell (embryophore). (*a.*)

(*a.*) Head unarmed with small apical fifth sucker.
Ripe proglottis 12 to 19 mm. long by 5 to 7 mm. wide; uterus with 20 to 30 slender lateral branches. *Tænia saginata.*
Ripe proglottis 7 mm. long by 12 to 15 mm. broad; uterus with 15 to 24 simple radiating branches. *Tænia africana.*

(*aa.*) Head armed with circlet of hooks.
Ripe proglottides 10 to 12 mm. long by 5 mm. wide; uterus with 7 to 10 thick branches; ovary on pore side divided by vagina. *Tænia solium.*

(*aaa.*) Head unknown.
Ripe proglottides 27 to 35 mm. long by 3.5 to 5 mm. wide; uterus with 14 to 18 heavy irregular forked branches. *Tænia confusa.*

(AA.) Small forms; eggs with thin transparent shells, in ripe proglottides grouped in capsules or irregularly distributed. (*b.*)

(*b.*) Genital pores unilateral.
Ripe proglottides broadly elliptical, 2 mm. long by 1.4 mm. wide. *Davainea madagascariensis.*
Ripe proglottides trapezoidal, 0.14 to 0.30 mm. long by 0.4 to 0.9 mm. wide. *Hymenolepis nana.*
Ripe proglottides trapezoidal, 0.75 mm. long by 2.5 mm. wide. *Hymenolepis diminuta.*

(*bb.*) Genital pores on both margins of each proglottis; genital organs also double.
Ripe proglottides elliptical. *Dipylidium caninum.*

(B.) Genital organs single in each proglottis.
Head elongated oval; length of worm 2 to 7 meters.
Ripe proglottides 2 to 4 mm. long by 10 to 12 mm. wide. *Dibothriocephalus latus.*
Head short, cordiform; length of worm hardly over 1 meter.
Ripe proglottides approximately 5 to 6 mm. square. *Dibothriocephalus cordatus.*

(BB.) Genital organs double in each proglottis.
Head not known; length about 10 meters.
Ripe proglottides 0.5 to 0.8 mm. long, 10 to 15 mm. wide. *Diplogonoporus grandis.*

In all cases reference should be made to the fuller descriptions given for each species in the text, and thus the results obtained by use of the brief criteria contained in the key controlled. Especial attention should be paid to those species which are as yet incompletely known; the writer will be glad to assist in the identification of any such.

The Cyclophyllidea possess a scolex with four circular suckers, often with an apical rostellum on which hooks are found when present. Segmentation is pronounced and the ripe proglottides do not separate until fully developed. There is no uterine aperture and the common sexual pore is located on the margin of the proglottides. The eggs are thin shelled and without a cover. The adults lie in the alimentary canal of the higher vertebrates. The order contains but a single family, the Tæniadæ.

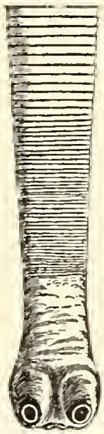
FIG. 1215.—Anterior End of *Tænia saginata*, Somewhat Contracted. × 8. (After Leuckart.)

For the genus *Taenia* the following characteristics are diagnostic. Large species with ripe proglottides much longer than broad. Uterus with median trunk and subsequently formed lateral branches during the development of which the remaining sexual organs disappear save cirrus and vagina. Larva, a cysticercus, cœnurus, or echinococcus, found in herbivorous mammals and also in man; adult in man and the carnivorous mammals.

TÆNIA SAGINATA Goeze.—T. inermis Brera, T. dentata Nicholai, T. lata Pruner, T. mediocanellata Küchenmeister, T. tropica Moq.-Tand.*

Length 4 to 8 meters or even to 74 meters (Bérenger-Féraud). Head (Fig. 1215) somewhat four-sided, 1.5 to 2 mm. in diameter, without rostellum and circle of hooks but with a sucker-like depression in its place which is often pigmented. Neck long, narrower than head. Proglottides number more than 1,000 and increase gradually in length until the ripe segments of characteristic pumpkin-seed appearance measure 16 to 20 mm. long by 4 to 7 mm. broad. Genital pores irregularly alternating, marginal, and posterior to the centre of the proglottis. Uterus in ripe proglottis with median stem and twenty to thirty-five slender lateral branches, themselves often branched. Egg shell delicate with one or two polar filaments (Fig. 1216), embryophore ovoid 35 to 40 μ by 20 to 30 μ in diameter. Adult exclusively in small intestine of man; larva (*Cysticercus bovis*) in the muscles and viscera of cattle.

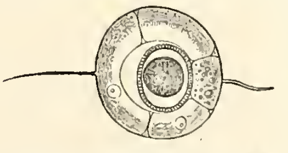
FIG. 1216.—Uterine Egg of *Tænia saginata* Showing Shell with Polar Filaments and in the Centre Onchosphere within the Embryophore. × 375. (After Leuckart.)

Structure.—The arrangement of the reproductive organs in a sexually mature proglottis (Fig. 1205) is best

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* Only the synonyms most frequently met are given under each species.

visible in a segment taken about 40 to 50 cm. from the head. The general structure of these organs has been described above. Characteristic for this species are the two ovaries of unequal size, that at the pore side being the smaller and without the small accessory lobe cut off by the vagina as in *T. solium.* The whole proglottis has a more open aspect, and the various organs show relatively greater antero-posterior diameter than in *T. solium.* The uterus in the ripe proglottis (Fig. 1207) manifests a more crowded structure, the lateral branches are slenderer and more numerous, and two or three are stunted or lacking opposite the sexual pore.

Development.—In 1861 Leuckart fed ripe proglottides of this species to calves and succeeded in obtaining the then unknown cysticercus, although various facts had pointed out cattle as the probable intermediate host. These results have been confirmed by many other investigators. At six weeks the size of the cysticercus (Fig. 1211), shelled out from its cyst, is: length 3 mm., breadth 5 mm., diameter of the head 1 mm.; at twelve weeks corresponding measurements are 4, 4, 1.8 mm. (length of head); at twenty-four weeks, 6, 4, 2 mm.; at forty-eight weeks 7, 5, 2.5 mm. The length of life of the cysticerci is brief; at less than eight months they have been found completely calcified. A temperature of 47° to 48° C. is always fatal. Of course the internal portions of roasting pieces are often far from reaching this temperature. On the other hand exposure to cold-storage conditions for three weeks is sufficient to destroy all these cysticerci contained in a piece of beef.

Artificial infection of man with the adult by eating flesh containing living specimens of *Cysticercus bovis* has been tried with equal success. An average growth of 72 mm., or about thirteen to fourteen proglottides daily, was determined.

Anomalies.—*T. saginata* appears to be peculiarly subject to variation and malformation. Excessive pigmentation of the head and chain led to the establishment of the species *T. nigra* Laboulbène (1875) for a tapeworm expelled by a Frenchman who had lived for some time in the United States. Two genital pores, on the same or opposite margins of the proglottis, but each connected with a set of reproductive organs, indicates the probable disappearance of the segmental boundaries, and this may be manifested over a considerable stretch of the worm, giving the appearance of an unsegmented body. Welch has observed such an unsegmented region 5 cm. in length. Intercalated proglottides or roughly triangular joints are not of infrequent occurrence. A common malformation consists in the perforation of a series of proglottides. This anomaly has received a specific name, *T. fenestrata,* at the hands of one observer. The fenestration appears first at the centre of the proglottis and becomes more accentuated toward the posterior end of the chain. Its cause is not understood.

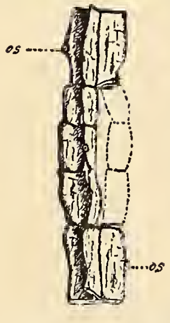

Fig. 1217.—Portion of the Chain from Prismatic Specimen of *Tænia saginata,* Showing also the Occasional Separation of the Three Wings for a Short Distance. os, Sexual Pore. Natural size. (After Cattaert.)

Finally there occurs a prismatic or triradial variety (Fig. 1217) which was described by Bremser as the result of the fusion of two individuals. The proglottis is Y-shaped in cross section, and the scolex bears six acetabula. Specimens of this sort were named *T. capensis* by Küchenmeister and *T. lophosoma* by Cobbold.

Onchospheres of *T. saginata* have been observed of considerable size, and armed with from twelve to twenty-two hooks; and Cobbold has described specimens of *Cysticercus bovis* from the heart of a calf with only three, two, one, and even no suckers on the head.

The form described by Weinland as *T. solium* var. *abietina,* from a specimen collected by Agassiz from a Chippewa Indian, is regarded by many as a small specimen of *T. saginata* with unusually dense and delicate branches of the uterus (Fig. 1218).

Distribution.—The adult occurs only in man and is cosmopolitan. Its presence in the Orient is recorded in writings of great antiquity; in Africa, Europe, and America it is also abundant, and its frequence has increased during recent years, whereas the contrary is true of *T. solium.* The evident reason lies in the custom of eating beef rare, but pork well done. The figures given by Bérenger-Féraud for French maritime hospitals during the six quinquennial periods from 1861 to 1890 show a steady relative increase of cases from 0.2 to 14.8 per mille. In Paris the increase, though real, was much less, being from 0.3 to 0.6 per cent. in the same time.

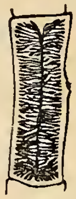

Fig. 1218.—Ripe Proglottis of *Tænia solium* (= *T. saginata* var.) var. *abietina* Weinland. (After Weinland.)

The larval form, *C. bovis,* has been produced experimentally in rare instances in other hosts, sheep and goat, but many experiments on these and other hosts have been entirely without results. In its normal host (cattle) the bladder worm was apparently rare, even in regions where *T. saginata* occurred abundantly. This apparent contradiction has been explained by the demonstration that in most cases normal infection is only mild and the cysticerci are so small and scattered as not to be easily found in the beef. Their predilection recently discovered for the pterygoid muscles affords, however, a surer means of diagnosis now than was formerly known.

A limited number of observations on the presence of *C. bovis* in man are on record. They include cases from the brain and eye, and the determination of the species rests on the absence of hooks and rostellum. Since, however, these organs may be wanting in *C. cellulosæ,* the larva of *T. solium* (*q. v.*), the determination in the cases under discussion must be viewed with suspicion.

Pathology.—Most common in hosts between twenty and forty years of age, the beef tapeworm has been encountered in the aged and even in newborn infants. Its normal place of fixation is near the pylorus, where the head is firmly fastened to the mucosa by its suckers. It may, however, be found exceptionally in the stomach. Symptoms of its presence are direct and local in the digestive system, or nervous and reflex in character. The latter are rarer but may be severe. A. Stieda has recently described a case in which this species, in spite of its lack of hooks, had bored through the wall of the duodenum and some distance in a circuitous course into the pancreas. In this case there were neither abcesses nor preformed orifices of which the worm could have made use, while other evidence supported the view of active burrowing on its part. Possibly the rare cases in which tapeworms have made their exit through the navel or bladder may be susceptible of a similar explanation. This is, however, the only case on record which has been subjected to a thorough scientific investigation.

The proglottides of this species are expelled spontaneously and in the interval between stools. The movements after expulsion are active and long continued as is evinced by the discovery of segments high on the walls of sick-room or outhouses. The anterior margin is lacerated by separation from the chain, and in crawling the proglottis distributes eggs from the uterine branches. These detached segments are frequently diagnosed as flukes, a conclusion apparently strongly confirmed by their independent activity.

This species cannot be regarded as equally dangerous with *T. solium* since here there is no chance for auto-infection by the onchospheres. The disturbances attending its presence in the alimentary canal, however, are such as to call for its removal. Despite the absence of hooks in the species this is, as a rule, more difficult of accomplishment than in the case of the pork tapeworm. The removal of the body without the head and neck constitutes but a temporary relief since a new chain is produced in a short time.

Tænia africana v. Linstow 1900.—Length 1.4 meters, greatest breadth 12 to 15 mm. Scolex unarmed, notably small, 1.4 mm. wide by 0.5 mm. long. Proglottides number about 600, decidedly broader than long; ripe proglottides measure 7 mm. long by 12 to 15 mm. broad. Uterus (Fig. 1219) with fifteen to twenty-four simple branches radiating from median trunk. Eggs thick shelled, 31 to 34 μ in diameter. Hooks of onchosphere 8 μ long. Adult parasitic in natives of German East Africa; development unknown.

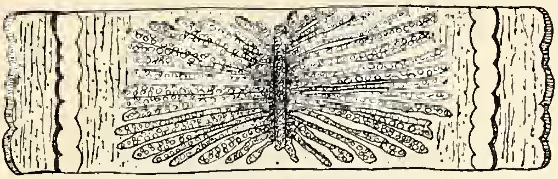
Fig. 1219.—Ripe Proglottis of *Tænia africana.* × 5. (After von Linstow.)

This species, only recently described, was obtained from black soldiers near Lake Nyassa in Africa. It differs radically from the common unarmed tapeworm of man, as is evident from examination of the sexually mature proglottis (Fig. 1220). Of importance in considering its development is the report that these natives are accustomed to eat the flesh of the zebu raw.

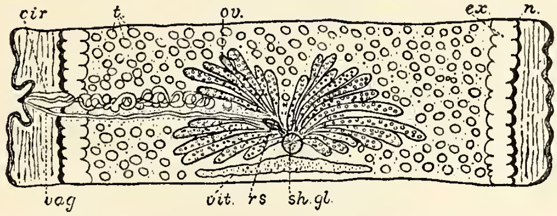

Fig. 1220.—Sexually Mature Proglottis of *Tænia africana.* *cir.*, Cirrus; *r.s.*, receptaculus seminis; *sh.gl.*, shell gland; *vag.*, vagina; *vit.*, vitellarium. × 5. (After von Linstow.)

Tænia solium L. 1767.—*T. pellucida* Goeze 1782 *T. vulgaris* Werner 1782, *T. solium* Rud. 1810. Length 2 to 3 meters, rarely 6 to 8 meters. Head (Fig. 1203) spherical 0.6–0.8 mm. in diameter. Rostrum short, often pigmented, with a double crown of twenty-four to thirty-two hooks in which large and small alternate regularly (Fig. 1221). Large hooks 0.16 to 0.18 mm. long, smaller 0.11 to 0.14 mm. long. Neck long and slender. Proglottides eight hundred to nine hundred in number, at 1 meter from the head square with sexual organs fully developed; at end of chain when ripe, 10–12 mm. long, 5–6 mm. broad. Uterus with prominent median stem and on each side seven to ten heavy branched lateral outpocketings. Embryophores 31-36 μ in diameter. Adult in small intestine of man; larva (*Cysticercus cellulosæ*) in muscles and viscera of domestic pig, rarely also of dog, man, and ape.

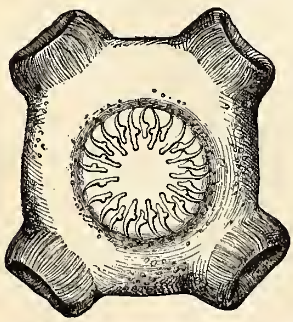
Fig. 1221.—Apical View of Scolex of *Tænia solium.* × 60. (After Leuckart.)

Structure.—In general appearance the pork tapeworm is distinctly more delicate and its chain less muscular than the beef tapeworm, previously described, and all its measurements display this difference. The scolex is decidedly smaller and has a prominent rostellum with two rows of hooks. The points of the hooks lie in a circle, but since they alternate regularly in size, the bases form two concentric circles. The hooks of the two sets show characteristic differences in figure (Fig. 1222) as well as in size.

The sexually mature proglottides do not exceed 4.5 to 5 mm. in width by 2.5 to 3 mm. in length, being thus decidedly inferior in size to those of *T. saginata.* On examination one sees the same organs in much the same relation as in the beef tapeworm; but there are minor differences which serve to distinguish the two species. Most prominent is the unequal size of the two ovaries (Fig. 1223), the one next the genital pore being the smaller and being oval in outline rather than circular. In addition a small ovarian lobe lies in the angle between the vagina and the uterus, as if cut off by the former canal from the ovary to which it apparently belongs. This accessory lobe is a constant and reliable peculiarity of the pork tapeworm. One may notice also the generally compressed form of the various organs most marked in the flattened vitellarium near the posterior edge of the proglottis.

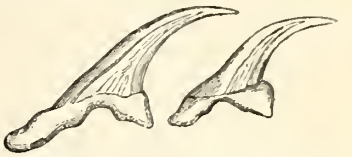
Fig. 1222.—Large and Small Hooks of *Tænia solium.* × 180. (After Leuckart.)

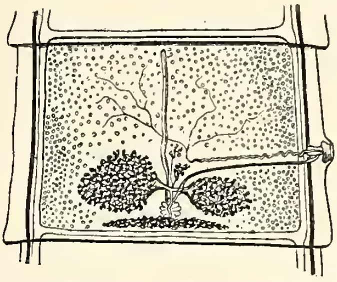
Fig. 1223.—Sexually Mature Proglottis of *Tænia solium,* Showing Reproductive Organs. × 10. (After Leuckart.)

The differences between the two species are less evident from examination of the ripe proglottides. Usually the segments of the pork tapeworm are given off in sets of two or three rather than singly. The individual proglottis is thinner, less muscular, in general also smaller and more transparent; yet these are highly variable features and often deceptive. The form of the uterus, however, gives to the proglottis a characteristic appearance. There are only seven to ten lateral branches which are more heavily and unevenly branched, while the ends of the branches are not infrequently enlarged (Fig. 1224).

Development.—The eggs (Fig. 1208) are oval, the outer shell is thin without polar filaments and transient; the inner shell is thick, radially striated, and spherical. The onchosphere is also spherical, measuring 20 μ in diameter. The development of the embryo is slow; in eight days it had only reached a size of 33 by 24 μ, and at the end of three weeks its diameter was but 0.8 mm., while in thirty-two days different individuals measured from 1 to 6 mm. by 0.7 to 2.5 mm. Even in the smallest, however, a head projection could be seen, and in the second month suckers and hooks are formed while the neck has grown so long as to produce one and a half complete circles within the bladder. By the close of the third month the bladder worm is probably ripe and capable of successful transference.

The longevity of the *Cysticercus cellulosæ* is dependent upon various circumstances. Not infrequently it degenerates at an early period, but more often later, by the loss of its liquid and by deposition of lime, into a mere calcareous granule. The same individual has, however, by means of the ophthalmoscope,

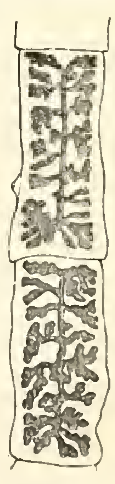
Fig. 1224.—Ripe Proglottides of *Tænia solium,* Showing Form of Uterine Branches. × 2. (After Braun.)

been observed living in the eye for twenty years. Free cysticerci live only a brief time in water, but in flesh at normal temperature they remain living up to twenty-nine days.

Many experiments have demonstrated that the *Cysticercus cellulosæ* of the pig, when introduced into the human alimentary canal, gives rise to *Tænia solium*. From ten to twelve weeks are necessary for full development and for the expulsion of the ripe proglottides. Efforts to bring the cysticercus to development in other hosts than man have as yet failed.

Anomalies.—Though less frequent than *T. saginata*, much the same malformations occur. Both incomplete and complete fusion of two or more segments and fenestration of parts of the chain are on record. An unusually slender structure of the chain gave rise to Cobbold's species, *T. tenella*, sometimes regarded as a distinct variety even yet. A scolex bearing six suckers has been observed both with an ordinary chain and with one of the prismatic or triradial variety with proglottides **Y**-shaped in cross section.

The onchosphere has at times more than the usual six hooks, and the *Cysticercus cellulosæ* is subject to various malformations. Absence of hooks, of a rostellum, and presence of six acetabula may be noted. Some abnormal forms have received special names; such a one is *C. racemosus* (*C. botyroides* or *C. multilocularis*) which is very irregular in form. This variety occurs especially at the base of the brain and is not surrounded by a cyst, to which, no doubt, is due its peculiar form, adapted to the space in which it lies. In some cases this variety is without a scolex or possesses at most but an abnormal rudiment of one.

Most interesting of all is the form which led to the establishment of a new species, *Cysticercus acanthotrias*, and by deduction a new tapeworm, *Tænia acanthotrias*. The *Cysticercus acanthotrias* was first observed by Weinland in 1858 at an autopsy of a white consumptive in Virginia. The bladder worms were in the dura mater, muscles, and subdermal tissues. Though in size and form like *C. cellulosæ*, these hydatids (Fig. 1225) possessed three rows, each of fourteen to sixteen hooks, longer and slenderer than those of that form and measuring severally 153 to 196 μ, 114 to 140 μ, and 63 to 70 μ. The discovery in several cases of identical bladder worms in European countries and the improbability of the existence there of an unknown large tapeworm with three circles of hooks, together with the occurrence in one case at least of this peculiar form side by side with *C. cellulosæ*, have led most investigators to regard *C. acanthotrias* as merely a variety of the common pork bladder worm.

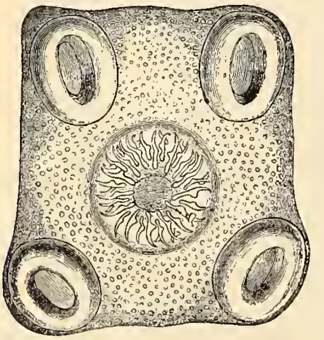

FIG. 1225.—Apical View of Scolex and Hooks of *Cysticercus acanthotrias*. × 50. (After Weinland.)

Distribution.—*Tænia solium* is not so widely distributed as *T. saginata*, although partaking of the cosmopolitan character of the latter. It is rare in tropical lands, and wanting among such races as abstain from the use of pork. On the other hand, especially in those regions where the inhabitants are accustomed to eat the flesh of the pig in a poorly cooked condition, the parasite is most abundant. Certain provinces of continental nations come within these limits. Contrary to the statements of a number of standard authorities, I am confident from the evidence gathered that this species is very rare at present in the United States. Some figures have been adduced to show that it is becoming decidedly rarer in both France and Germany. In Denmark it was, in 1869, the commonest human cestode, being present in 53 out of 100 cases; in 1887–95 it was not found once in 100 cases (Krabbe).

Cysticercus cellulosæ is present not only in the pig but also in the wild boar, deer, dog, cat, rat, brown bear, ape, and even man himself. In the pig the bladder worm is more abundant in such animals as are allowed to range than in those that are stall fed. In Germany the ratio of infected animals varies in different provinces from 1 in 100 to 1 in 2,000 according to reports of meat inspectors. As these cover, however, only the cases in which the infection is prominent, the actual figures are much larger. Leuckart calculated some years ago that two to three pigs per hundred were infected. This bladder worm also seems to be growing rarer during recent years.

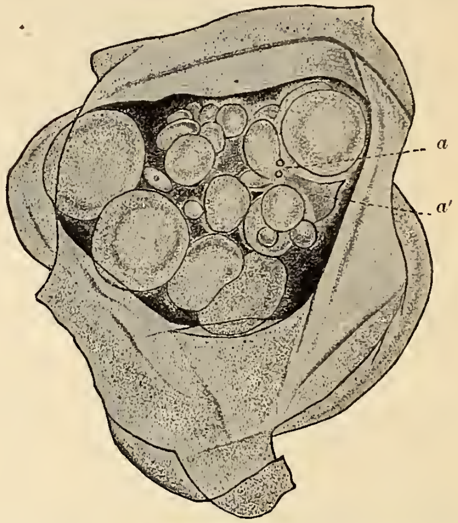

FIG. 1226.—Brain Cysticercus. Fresh specimen opened to show internal structure. *a-a'*, Stalk of racemose body (scolex). × 3. (After Kratter and Böhmig.)

Pathology.—*Tænia solium* lies with the head fastened in the anterior portion of the small intestine. The proglottides are passed in groups with fæcal matter; exceptionally through abnormal communications they reach the body cavity, bladder, and abscesses, or finally are thrown out *per os* by vomiting. The troubles caused by the worm do not differ from those due to *T. saginata*, yet the former is a much more dangerous parasite since its bladder worm may also develop in man. When abundant the bladder worms produce in pork the conditions known as "measles," and measly pork is the ordinary means of introducing *T. solium* into the human system. Rarely it may be caused by the consumption of the infected flesh of the wild pig or deer. Smoking and salting, unless extended and thorough, will not kill the bladder worms in pork and ham. Thorough cooking, however, renders them entirely harmless. As early as 1558 the cysticerci were observed in the dura mater of an epileptic. While the brain and eye are apparently the most frequent seats of the bladder worms, the latter occur also in the muscles, subdermal tissue, heart, lung, liver, peritoneum, etc. Particularly dangerous are, of course, the cerebral cysticerci (Fig. 1226) which produce effects parallel to brain tumors. In this location they are not rarely the cause of sudden death. According to Verdun and Iversenc the bladder worm of the cerebral vesicles is ordinarily free and not of the racemose variety. The acephalocystic vesicle is most common, next comes the simple form with a single head, and rarest are those consisting of a few vesicles united by the stalk. The fourth ventricle is the most frequent location of the parasite. The symptoms due to the presence of such cysticerci do not permit of certain diagnosis; most general are, however, signs of compression due to ventricular hydrocephaly.

The introduction of the onchospheres into the human stomach, which is a necessary preliminary to further development in the system, is brought about by impure drinking-water, by the use of salads or uncooked vegetables contaminated by the embryophores, and by the careless use of unsanitary closets. More frequently, no doubt, the host of the adult tapeworm infects himself through lack of cleanliness in defæcation, or possibly, as has been suggested, by internal auto-infection. Any circumstances which might lead to the passage of adult proglottides containing ripe onchospheres from the intestine back into the stomach would result in infection by those onchospheres which remained there a short time as if they had been introduced through the mouth.

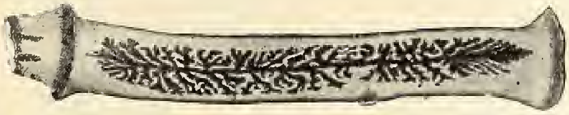

FIG. 1227.—Ripe Proglottis of *Tænia confusa*. × 2.5. (Original photomicrograph.)

The danger of internal or external auto-infection demands immediate action by the physician for the removal of the parasite under great care that all regurgitation should be prevented. The success of the operation must be confirmed by the discovery of the tapeworm head, and the parasite destroyed rather than merely thrown away.

TÆNIA CONFUSA Ward 1896.—This species, originally described by the writer and later studied in greater detail by one of his students (Guyer), was obtained in Lincoln, Neb. In general appearance it is much like the two species just described, but may be recognized at once by the extraordinary length of the ripe proglottides, some measuring as much as 35 mm. long by only 4 to 5 mm. broad. The shape of these proglottides differs also from that of the terminal segments in the other species (Fig. 1227, *cf.* Fig. 1207 and Fig. 1224). The head of this species is unknown, consequently its exact position and relationship are for the time being uncertain. The whole body is thinner and more fragile than that of *T. saginata*. It measures 5 to 8 meters in length and has some seven hundred to eight hundred proglottides, nearly all of which are longer than broad. The sexually mature proglottides (Fig. 1228) are distinguishable by the long reniform lobes of the ovary. In the ripe proglottides the median stem of the uterus bears fourteen to eighteen irregularly branching offshoots swollen at the end into irregular club-shaped masses. Of the approximately forty points of difference in structure between this and the common species, *T. saginata* and *T. solium*, as tabulated by Guyer, the most important are subjoined. Nothing is known of the life history of this species.

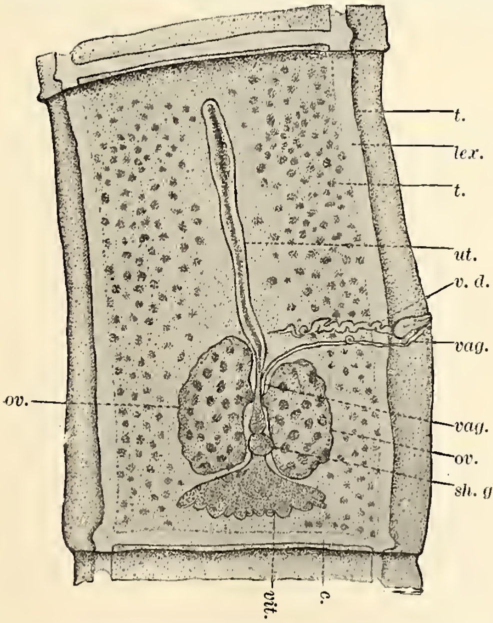

FIG. 1228.—Sexually Mature Proglottis of *Tænia confusa*. × 15. (After Guyer.)

	T. saginata.	T. solium.	T. confusa.
Size of terminal proglottides.	12–19 mm. long by 5–6.5 mm. wide.	10–12 mm. long by 5 mm. wide	27–35 mm. long by 3.5–5 mm. wide.
Greatest breadth..	12–14 mm	7–8 mm	8–10 mm.
Length of proglottides exceeds breadth.	Only in last 100.	In last half.....	In nearly entire worm.
Proglottides 35 cm. behind head measure.	1.5–2.6 mm. long by 5–10 mm. wide.	0.8 mm. long by 1.3 mm. wide.	1–2.5 mm. long by 0.8–3 mm. wide.
Sexually mature proglottides measure.	4–6 mm. long, 8–10 mm. wide	2.5–3 mm. long 4.5–5 mm. wide.	4–4.5 mm. long, 3.5–4.5 mm. wide.
Neck is..........	Unsegmented...	Unsegmented ..	Segmented.
Calcareous bodies.	Abundant; to 0.018 mm.	Sparse; to 0.012 mm.	Sparse; to 0.011 mm.
Longitudinal nerve trunks.	Dorsal to genital ducts.	Ibidem.........	Divide, passing both dorsal and ventral to ducts.
Depth of genital cloaca.	0.22 mm.......	Smaller	0.05–0.08 mm.
Width of genital pore.	1 mm..........	Smaller	0.45–0.6 mm.
Ovarian lobes....	Round	Part of smaller cut off by vagina.	Reniform.
Lateral branches of uterus.	20–30	7–10...........	14–18
Size and form of eggs.	0.03 mm., slightly oval.	0.03 mm., nearly round.	0.039 by 0.03 mm., oval.
Pyriform process.	Present	In young proglottides.	Absent entirely.

Further information is needed regarding the frequence and distribution of this form, which though distinguishable on careful examination, has doubtless often been regarded as the common species—whence the name *confusa*.

TÆNIA SERRATA Goeze 1782.—Length 0.5 to 2 meters. Head 1.3 mm. in diameter with a double crown of thirty-four to forty-eight hooks, the larger 225 to 250 μ long, the smaller 120 to 160 μ. Embryophores oval, 36–40 μ by 31-36 μ. Adult in small intestine of dog; larva (*Cysticercus pisiformis*) in peritoneum of rabbits.

The single record of its presence in man, reported from Algeria, is undoubtedly an error in the determination of the species found. In its normal host it is common everywhere in Europe and America so far as the records stand at present.

TÆNIA CRASSICOLLIS Rud. 1810.—Length 0.15 to 0.6 meter. Head 1.7 mm. in diameter with a double crown of twenty-six to fifty-two hooks, the larger 380–420 μ long, the smaller 250–270 μ. Embryophores spherical, 31 to 37 μ in diameter. Adult in small intestine of domestic cat and related wild species; larva (*Cysticercus fasciolaris*) in rats, mice, etc.

Braun records after Krabbe that in Jutland chopped mice are consumed uncooked on bread as a popular medicament against enuresis. Evidently the introduction of living larvæ of this species into the human alimentary canal would be not only possible but probable under these circumstances.

TÆNIA MARGINATA Batsch 1786.—Length 1.5 to 5 meters. Head reniform, 1 mm. in diameter. Hooks thirty to forty-four in a double row; the larger measure 180 to 220 μ in length, the smaller 110 to 160 μ. Ripe proglottides 10 to 14 mm. by 4 to 7 mm. Uterus with short main trunk and five to eight large branches on each side. Embryophores spherical, 31 to 36 μ in diameter.

The adult lives in the small intestine of dog and wolf; larva (*Cysticercus tenuicollis*) is found in the peritoneum of apes, ruminants, and pigs. Experiment has shown that the larva will not develop to the adult worm in the human alimentary canal. The larva has been reported twice as a human parasite; but the record of its presence in the liver of man in Iceland has been shown to be a mistake. Hodges also reported its occurrence in man in the United States; but Wyman, who examined the specimens, stated that the hooks resembled rather those of *Cysticercus cellulosæ,* while the size of the cyst and the number of hooks favored *C. tenuicollis.* Since the latter features are known to be much more variable than the former, it is probable that the determination is erroneous in this case also.

Since the most dangerous of all human parasites is a dog tapeworm, and since several other canine cestodes are either known to be found or suspected to be parasitic in man at some age or in some stage of life, the dog tapeworms are evidently most important for the physician from the sanitary point of view, quite apart from the fact that by virtue of their serious effects on other domestic animals these cestodes demand attention from an economic standpoint. A strict control should be exercised over the condition of the dog in every household where such a pet is found, and the removal of the army of stray curs should be urged in every community; for these vagrants are the very ones most likely, by virtue of their omnivorous habits, to become infected and, in consequence of their nomadic life, to carry parasites from place to place. The presence of tapeworms in dogs may be recognized by the proglottides found in the fæces, and I have known of such having been taken from the back of a dog and submitted to a physician as a curiosity! Manifestation of an anal or subcaudal pruritus on the part of the dog is also good evidence of their presence. In all such cases the health of the family demands that the physician insist on the treatment of the dog for their removal.

As the determination of the species may be of importance in such cases there is appended a table, modified from Neumann, of the canine cestodes thus far reported:

- Four suckers on the head.
  - Head armed; genital pore marginal and—
    - Single.
      - Numerous proglottides. Strobila several centimeters long. Segments—
        - Never more than slightly broader than long. Small hooks with guard—
          - Bifid; hooks
            - 230-260 μ long, genital pore very salient. *Tænia serrata.*
            - 136-157 μ long, genital pore not very salient. *T. serialis.*
          - Entire; large hooks—
            - 180-220 μ long, length of mature segments double that of their width. *T. marginata.*
            - 150-170 μ long, length of mature segments treble their width. *T. cœnurus.*
        - Much broader than long except the distal segments which suddenly elongate; genital pore usually large and prominent. *T. Krabbei.*
      - Three or four segments; some millimeters long .... *T. echinococcus.*
    - Double and bilateral .... *Dipylidium caninum.*
  - Head unarmed. Sexual orifices on the ventral surface .... *Mesocestoides lineatus.*
- Two suckers on the head; genital pores on the ventral surface .... *Dibothriocephalus fuscus.*

Tænia echinococcus von Siebold 1853.—Small cestodes (Fig. 1229) measuring from 2.5 to 5 or 6 mm. in length with only three to four proglottides the last of which measures when ripe 2 mm. in length by 0.6 mm. in breadth. Head 0.3 mm. broad with prominent rostellum bearing in a double row twenty-eight to fifty hooks which vary considerably in form and size. Onchospheres oval, 32–36 μ by 25–30 μ. Adult found in large numbers in small intestine of dog, wolf, jackal, dingo; the larva (*Echinococcus polymorphus*) in many organs of a multitude of hosts, including man.

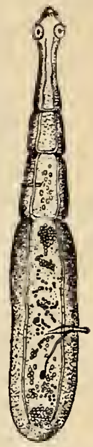
Fig. 1229.—Entire Specimen of *Tænia echinococcus* from the Dog. × 12. (After Claus.)

Structure.—The adult of this species was long regarded as an immature form by virtue of its small size and limited number of proglottides until von Siebold produced it by feeding dogs with echinococcus bladders from sheep. The experiment has been repeated successfully many times with echinococcus from various sources including man, and shows a developmental period of seven to eight weeks to be necessary for the production of ripe individuals. The experimental production of the echinococcus has proved more difficult, but Leuckart has succeeded in following it by feeding the adult tapeworms to suckling pigs. The development proceeds so slowly that in one month there has been formed a spherical solid only 0.25 to 0.35 mm. in diameter enclosed in a connective-tissue cyst formed by the host, the entire mass making nodules in the liver barely 1 mm. in diameter. At two months the larvæ are twice as large, the wall consists of a thick external lamellar cuticula and a delicate granular internal membrane enclosing a watery fluid. At five months the diameter of the parasite has become 10–12 mm., but no structure is yet visible in the interior. To the parasite in this condition, consisting of cuticula, parenchyma layer (endocyst), and fluid contents, the name Acephalocystis has been applied by some authors, and frequently the organism makes no advance in structure beyond this condition. Normally, however, there appears a protuberance on the endocyst (Fig. 1230, *a*) which develops rapidly into a brood capsule (*b*) in which the parenchyma is external and the cuticular layer internal. According to the views of some investigators these may become detached and continue their development floating (*f*) in the cavity of the mother cyst, in which case, however, a cuticular layer is formed on the outside and disappears within. In the opinion of others such free daughter cysts or secondary capsules arise in the wall of the parasite when a cuticular layer is formed about small centres of detached parenchyma; as these grow they burst out from the wall, and if they fall within the mother cyst and continue their development within the cavity of the latter, the form known as an endogenous echinococcus is produced; this variety occurs most frequently in man, pig, and horse. If, on the other hand, the daughter cysts burst out from the wall of the mother cyst, their continued growth (*g–l*) outside gives rise to exogenous echinococci. Evidently a group of several distinct individuals may easily be confounded with a group consisting of mother and daughter cysts. Further development may also give rise to a third generation of cysts inside the second (*l*). Any or all capsules may remain sterile, *i.e.*, without heads, and such are the acephalocystic forms noted above. In most cases, however, heads are formed on the brood capsules or on the secondary cysts. According to the recent investigations of Goldschmidt a proliferation of the parenchyma layer in a brood capsule forms a low elevation (*m*). As this grows there arises inside the capsule an annular furrow, and this growing outward cuts off a pyramidal elevation (*n*) which by virtue of its early developed muscles displays great mobility, hanging outward from the brood capsule (*o*) or thrusting itself into the same as a solid linguiform structure (*p*). The external chitinous covering of the fully formed head takes its origin in a second annular furrow outside the first, which gradually surrounds the parts already described (*q*) and on its completion leaves the head projecting into the cavity of the brood capsule. Suckers and hooks originate and the entire structure presents the form of an inverted scolex (*r*). In each daughter cyst (*d*, *e*) five to ten, or even as many as thirty-four heads may develop, so that the entire number in one echinococcus reaches into the thousands. By the rupture of the brood capsule scolices may extend directly into the cavity of the hydatid or even be found floating free in its contents. The echinococcus is now mature, and if eaten by a suitable host these scolices will develop in its alimentary canal into adult tapeworms.

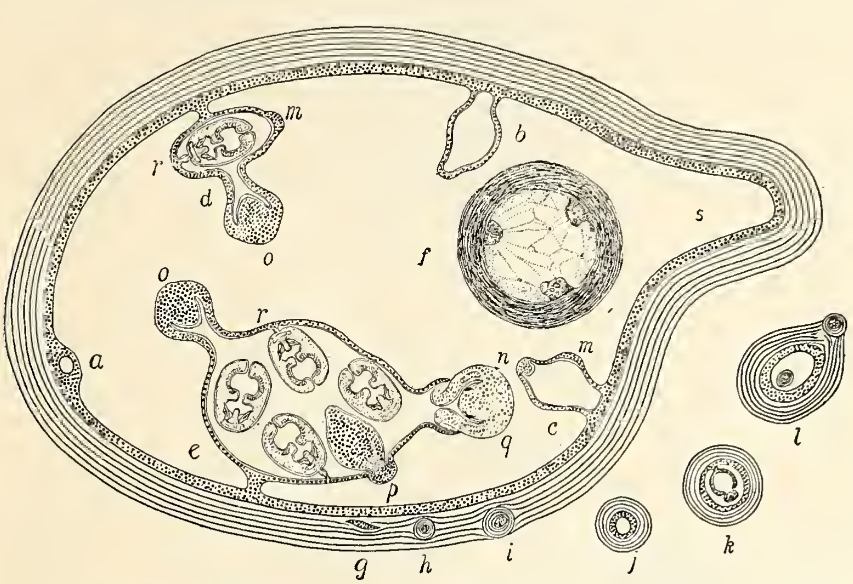

FIG. 1230.—Diagrammatic Representation of Echinococcus Seen in Section. *a*, Origin of a brood capsule; *b*, *c*, *d*, further stages in its development; *e*, fully developed brood capsule; *f*, endogenous daughter cyst formed from brood capsule; *g*, origin of an exogenous daughter cyst; *h*, *i*, *j*, *k*, its further development; *l*, an exogenous daughter cyst forming an exogenous and an endogenous cyst of the third generation; *m*, origin of a scolex as a minute elevation in the wall of a brood capsule; *n*, its delimitation by a shallow internal groove; *o*, later stage; *p*, the same as last, but invaginated; *q*, the enclosing of the papilla by a second outer furrow; *r*, a fully developed scolex with head inverted. (Original.) S ?

The form of the hydatid cyst is subject to considerable variation, the more extreme types of which have received special names. Evaginations in the wall (*s*) frequently occur under mechanical influences in the environment and suggest the origin of the form known as *E. racemosus* (Fig. 1231), from which, however, *E. multilocularis* cannot be distinctly separated in all cases. The latter, known also as an alveolar colloid, represents a mass of many small hydatids 0.1 to 5 mm. in diameter which in section display numerous irregular cavities filled with a transparent gelatinous substance and embedded in a common stroma of connective tissue. Gall duct and blood-vessels may be detected in places, but the liver cells are completely atrophied. These growths were long interpreted as colloid cancers until Virchow demonstrated their hydatid origin. The scolices or hooks, often rare and single or at most few in any bladder, are entirely wanting in forty per cent. of the specimens tested. These multilocular hydatids undergo regularly degenerative processes by which a central cavity is formed filled with a fluid containing among tissue remnants also calcareous corpuscles, secondary bladders, brood capsules, scolices, hooks, hæmatoidin and margarin crystals, concretions, etc. The size of the hooks (Fig. 1232), which varies very considerably, is due, as Leuckart has shown, to the age and stage of development of the specimen.

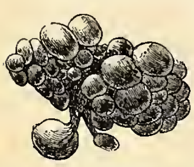

FIG. 1231.—*Echinococcus racemosus*. Natural size. (After Leuckart.)

Anomalies.—A specimen of *T. echinococcus* has been described with six suckers on the head. Regarding the larval form some observers hold that the varieties noted above as *Acephalocystis*, *E. racemosus*, and *E. multilocularis* are abnormal. According to others the latter form, which appears to be confined to Switzerland, represents a different species from the common type. Isolated cases have, however, been reported from other localities, one even from the United States (Stiles).

Distribution. — The adult parasite appears to be most common in Iceland, where it occurred in 28 per cent. of the dogs examined. In Australia the percentage is even higher, 40 to 50 per cent. being recorded. On the continent of Europe it occurs in from 0.4 to 7 per cent. of the dogs examined in different localities. Stiles records its presence, though very rarely, in dogs examined at Washington, D. C. I have found no other record of the presence of the adult tapeworm in this country. When present its occurrence in large numbers is natural. The hydatid is most abundant in Iceland and in India, where from one-fourth to three-fourths of all domestic animals are infected. In Germany, where records are of a most precise nature, the percentage of infection varies very greatly, being as low as 5 per cent. in a few cases and as high as 65 per cent. in one locality (for precise figures see Stiles and Hassall, p. 122). In the United States hydatids have been recorded from cattle, hog, and camel, and for localities in Maryland, the District of Columbia, Missouri, Nebraska, and Louisiana. In New Orleans 117 cases of liver echinococcus were recorded from 2,000 hogs.

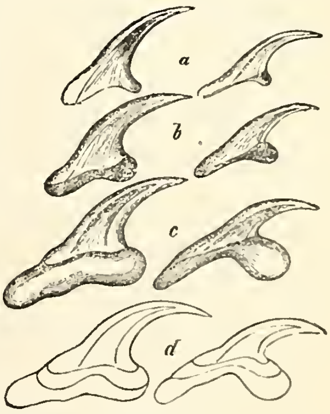

FIG. 1232.—Echinococcus Hooks. *a*, From bladder worm of cow; *b*, from young *Tænia echinococcus*; *c*, from adult *Tænia echinococcus*; *d*, the three forms superposed to show gradual modification in form. × 500. (After Leuckart.)

In man the frequency of hydatid disease corresponds in general with that for domestic animals. In Iceland estimates of the number of inhabitants infected vary from 2 to 15 per cent.; in Australia 3,000 cases were reported between the years 1861 and 1882. In Europe the results of autopsies are given in the table at the top of the next page, which is taken from Ostertag.

In this country the hydatid is rare in man. Sommer has compiled statistics of one hundred recorded cases

Locality.	Total number of autopsies.	Hydatids Present.	
		Cases.	Percentage.
Rostock	1,025	25	2.43
Breslau	1,360	20	1.47
Berlin	4,470	33	.76
Göttingen	639	3	.46
Dresden	2,002	7	.34
Vienna	1,229	3	.24
Prague	1,287	3	.23
Erlangen	1,812	2	.11

from which the following data are taken. It is entirely unknown how many patients were infected outside the limits of this continent; certainly some of them acquired the parasite in other countries.

By Sex.

Males	47
Females	28
Unstated	25

By Nativity.

Azorian	1
Colored	1
English	5
Foreigners	2
French	2
German	15
Irish	2
Italian	5
Japanese	1
Mexican	1
Mulatto	2
Negro	2
Pole	1
Swede	1
Welsh	1
White	4
Unstated	54
Total	100

By States.

Alabama	2
California	1
Connecticut	1
District of Columbia	4
Illinois	3
Indiana	1
Kentucky	2
Louisiana	1 (or 2?)
Massachusetts	5 (or 6?)
Michigan	1
Missouri	7
New Jersey	1
New York	33
Ohio	7
Pennsylvania	10
Tennessee	1
Texas	1 (+ ?)
Vermont	1
Virginia	2
Washington	1
Unstated	15
Total	100

Caution should be exercised in the identification of supposed echinococcus bladders from domestic animals since the hydatid of *Tænia serialis* of the dog, which is abundant in the United States, is large, at times even of very considerable size, and produces numerous secondary bladders both internally and externally, so that the general appearance suggests that of echinococcus. The size and form of the scolices and of the hooks are so very different that even a superficial microscopic examination serves to distinguish the two forms. The hydatid of *Tænia serialis* is common in the rabbit and has also been reported from the horse.

Pathology.—The larva gives rise to the hydatid or echinococcus disease, the symptoms of which vary with the seat of the parasite. Cases are on record in which the hydatid has existed for 2, 4, 8, 15, 18, and even 30 years in man. It may be found in any organ, but is most frequently recorded from the liver or lungs. At times its presence is not suspected until revealed by post-mortem examination; and the danger depends in any case upon the precise location and the size attained by the hydatid. In some situations hydatids exert a fatal pressure upon important vessels or nerves or destroy the tissue of essential organs. They often cause fatal results by bursting into a serous cavity or a blood-vessel, the toxic effect of the fluid having been noted already. Somer gives the following table for 1,806 cases recorded in various countries:

Classification by Habitat.

	United States.	Canada.	Other countries.	Total.
Liver	62	7	942	1,011
Lung	7	..	140	147
Passed *per rectum*	2	..	....	2
Spleen	3	2	37	42
Brain	3	..	....	3
Abdominal wall	1	..	....	1
Vomited	2	..	....	2
Expectorated	2	..	....	2
Common bile duct	2	..	....	2
Bones	1	..	....	1
Bladder	6	..	....	6
Eye	1	..	....	1
Pericardium	1	..	....	1
Ovaries	1	..	....	1
Uterus	3	..	....	3
Trunk and limbs	..	..	4	4
Kidneys	3	..	123	126
Neck (fascia)	1	..	....	1
Stomach	1	1	....	2
Extensors of thigh	1	..	....	1
Pleura	1	..	19	20
Circulatory apparatus	..	..	53	53
Cranial cavity	..	..	91	91
Spinal canal	..	..	13	13
Pelvis	3	2	70	75
Peritoneum and omentum	1	..	61	62
Mesentery and omentum	1	..	....	1
Female genital organs and mammaries	..	..	60	60
Male genital organs	..	..	9	9
Face, orbit, and mouth	..	..	41	41
Neck	..	..	18	18
Abdomen	2	..	....	2
Omentum	1	..	....	1
Brain (ventricles)	1	..	....	1
Totals	113	12	1,681	1,806

Prevention.—As "hydatid disease is the most fatal zooparasite disease which affects man, fifty per cent. of the cases dying within five years after infection," too great insistence cannot be laid upon the necessity of guarding against the disease and stamping it out. Measures should be taken to destroy all stray dogs, to prohibit the presence of dogs at abattoirs, to destroy all hydatids found in slaughtered animals, and to discourage all intimate association with dogs. Methods for the treatment of echinococcus diseases in man have been suggested, but surgical interference alone has met with satisfactory results.

Davainea R. Blanchard 1891.—Small cestodes with prominent rostellum, sometimes retractile, armed with many small hooks of characteristic form, which may be caducous. Genital pores unilateral, or alternating irregularly. Eggs in capsules. Development unknown.

Davainea madagascariensis R. Blanchard 1891; *Tænia demerariensis* C. W. Daniels 1895.—Length up to 24 cm. with five hundred to six hundred proglottides. Head (Fig. 1233) with retractile rostellum having ninety hooks, 18 μ in length, which may be wanting. Genital pores unilateral. Ripe proglottides 2 mm. long, 1.4 mm. broad. Eggs in groups surrounded by heavy capsules of parenchyma forming the characteristic egg balls which fill the entire ripe proglottides. Oncospheres 8 μ in diameter with six delicate nearly straight hooks, surrounded by two transparent membranes of which the outer has two pointed prolongations.

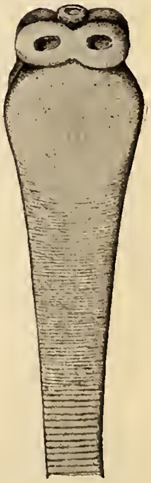

Fig. 1233.—Anterior End of *Davainea madagascariensis*. × 14. (After Blanchard.)

The growth of the cestode is very rapid. At 3 cm. from the head proglottides may be seen in copula. The last hundred segments, which make up more than half of the entire length of the worm, contain only eggs about which the capsules are forming. The characteristic appearance of the ripe proglottis is given in the figure (Fig. 1234). Of the development nothing is known. Blanchard surmises that the larval host is a cosmopolitan insect (*e.g.*, cockroach), which tallies well with known facts regarding the parasite.

Ten cases of the occurrence of this cestode in man are on record; they are distributed over the tropics, including both hemispheres. With one exception all individuals affected were infants or children. Although not yet recorded from any other host, it should be noted that the species may be only an adventitious parasite of man.

HYMENOLEPIS Weinland 1858; *Diplacanthus* Weinland.—Scolex small, rostellum retractile, armed; suckers unarmed. Genital pores on left margin; three testes in each proglottis. Ripe uterus fills entire proglottis. Eggs spherical or elongated with three widely separated membranes. Larval stage a cercocystis or staphylocystis.

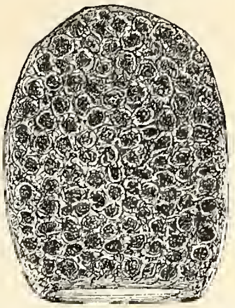
FIG. 1234.—Ripe Proglottis of *Davainea madagascariensis* just Liberated from the Chain. × 10. (After Davaine.)

HYMENOLEPIS NANA R. Blanchard 1891; *T. ægyptiaca* Bilharz, *Diplacanthus nanus* Weinland.—Length (Fig. 1235) 10 to 15 mm. rarely 20 mm., breadth 0.5 to 0.7 mm. Spherical scolex (Fig. 1236) 0.25 to 0.3 mm. in diameter with retractile rostellum armed with a single circle of twenty-four to thirty hooks which are only 14 to 18 μ long. Neck long, proglottides about one hundred and fifty in number, very short, the largest measuring only 0.4 to 0.9 mm. wide by 0.14 to 0.3 mm. long. External egg membrane measures 30 to 40 rarely 50 μ, in diameter, the onchosphere membrane 16 to 20 μ. Adult in the small intestine of man.

The development of this species is still unknown. Grassi regards it as identical with *H. murina* from the rat. According to his investigations this latter form develops directly without any secondary host, so that the chance consumption of ripe proglottides or of onchospheres would ultimately produce the adult tapeworm. Other authors have emphasized a series of differences in detail which militate against the identity of the two forms. In experiments with six persons who had swallowed ripe proglottides of *H. murina*, Grassi obtained specimens of *H. nana* only once, which in a region where the latter is abundant proves nothing. On the other hand the same investigator was unable to infect rats by feeding them ripe proglottides of *H. nana*. The evidently close relationship of the two species is presumption in favor of a similar mode of development.

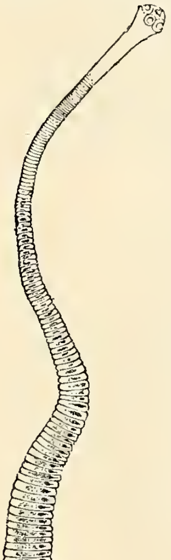
FIG. 1235.—Entire Specimen of *Hymenolepis nana*. × 15. (After Leuckart.)

Discovered in 1851 by Bilharz in Egypt it has been reported occasionally from Russia, Germany, England, France, Argentine, and the United States. In Italy it appears to be comparatively abundant. The single record of its occurrence in the United States (Spooner, 1873) is somewhat uncertain since the author mentions the possibility that the form described belonged to the following species.

Hymenolepis nana has been found chiefly in infants, less commonly in children, and only very rarely in adults. It occurs in considerable numbers, two hundred and fifty to one thousand and over, and gives rise to more serious disturbances than are attributable to the large cestodes. In addition to gastric disturbances, secondary reflex nervous symptoms, even epilepsy, have been observed; though of long standing they disappear with the removal of the parasites.

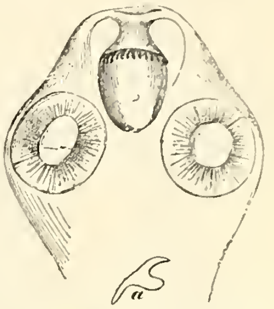

FIG. 1236.—Scolex of *Hymenolepis nana* with Rostellum Retracted. × 80. *a*, Isolated hook. × 480. (After Leuckart.)

HYMENOLEPIS DIMINUTA R. Blanchard 1891; *T. diminuta* Rud., *T. leptocephala* Creplin, *T. flavopunctata* Weinland, *T. varesina* Parona, *T. minima* Grassi.—Length 20 to 60 cm., width 3.5 mm. Head (Fig. 1237) small, claviform, with rudimentary unarmed rostellum. Neck short. Proglottides short and indistinct at first, increasing gradually to a maximum near the posterior end of the chain of 0.66 mm. long by 3.5 mm. wide. External egg membrane, 60 to 86 μ in length, internal with polar projections; onchospheres, 36 by 28 μ. Adults in small intestine of various rats and mice, and rarely also of man; larvæ (cercocystis) in various insects, chiefly the meal worm (*Asopia farinalis*).

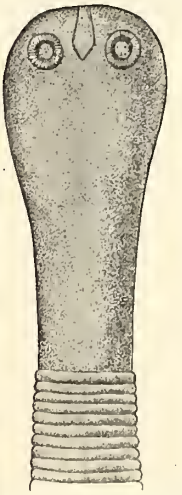
FIG. 1237.—Anterior End of *Hymenolepis diminuta*. Magnified. (After Zschokke.)

The structure of the species is typical for the group. It has been studied with great care by Zschokke. The arrangement of organs in the sexually mature proglottides is evident from the figure given (Fig. 1238). In the ripe proglottis the egg-filled uterus occupies the entire space within the walls of the segment save for the large flask-shaped cirrus. Sterile proglottides of smaller size and without eggs occur at times in the series.

The larval form, a cercocystis, occurs in many insects, Lepidoptera, Coleoptera, and Orthoptera. Its usual host is the larva and adult of a small moth (*Asopia*). The development to the adult form has been observed in white rats and in man where some fifteen days intervene before the appearance of ripe eggs in the fæces.

This species was first collected from man in Boston in 1842, and described by Weinland in 1858, who regarded it as a new species, *T. flavopunctata*. In 1884 Leidy recorded it from Philadelphia. It has also been observed as a human parasite in Italy and France, and may be met with more widely since its normal host, the rat, is a cosmopolite.

Heretofore it has been found only in infants and children, and the introduction of the larval parasite was probably due to eating fruit or other food in which an infected insect or grub was concealed.

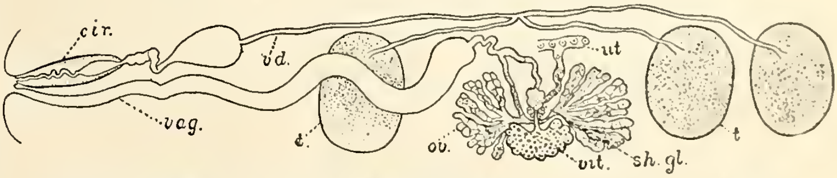

FIG. 1238.—Reproductive Organs of *Hymenolepis diminuta*. (Letters as before.) Magnified. (After Zschokke.)

Dipylidium R. Leuckart 1863.—Rostellum retractible, armed with several annular rows of alternating hooks. Genital pores opposite, organs doubled. Uterus at first a reticulum, which later becomes changed into sacs holding one or more eggs each. Eggs with double shell.

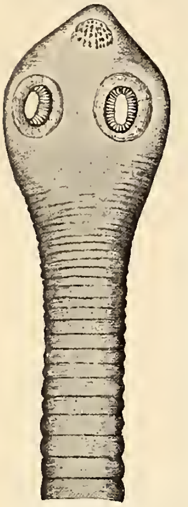
Fig. 1239.—Anterior End of *Dipylidium caninum.* (Original.)

Dipylidium caninum Railliet 1893; *T. moniliformis* Pallas, *T. cucumerina* Bloch, *T. elliptica* Batsch.—Length 10 to 40 cm., greatest width 1.5 to 3 mm. Scolex (Fig. 1239) small with retractile claviform rostellum armed with three or four rows of thorn-shaped hooks which decrease in size from 15 μ in the first row to 6 μ in the last; suckers elliptical, neck short. First proglottides small, becoming trapezoidal and finally characteristically of melon-seed form. Eggs spherical, 43–50 μ in diameter; onchosphere, 32 to 36 μ in diameter. Adult parasitic in the small intestine of the dog, cat, and rarely also man; larva (cryptocystis) in the body cavity of the dog flea and dog louse.

The most striking feature of the structure of this species is the doubling of the reproductive organs, a complete set with genital pores and copulatory organs being present on each side of the proglottis (Fig. 1240). The branches of the uterus, however, become cut off as small capsules containing eight to twelve eggs each; in the ripe proglottis the mass of such capsules fills the entire middle field, and a reddish-brown substance deposited around the eggs imparts a characteristic pink color to these segments. Prismatic and fenestrated specimens have been observed, and also individuals in which four sets of organs lay in a single proglottis.

The onchosphere is transformed in the body cavity of the dog flea, or even of the human flea, into a tailed larva, or cryptocystis. When the dogs, annoyed by the work of the fleas, hunt out and destroy these pests, it is easy to see how they infect themselves.

With a single exception all recorded cases of this tapeworm in man are among children who have by some chance obtained the larva of the parasite from playing with dogs. The first case on record dates from Linnæus, and other cases have been reported from England, Germany, France, Russia, and Scandinavia. Judging from the frequence of the parasite in dogs in this country, similar cases should not be rare here. I have found none definitely recorded.

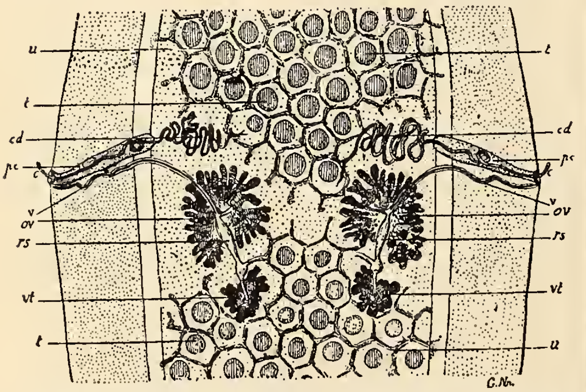

Fig. 1240.—Median Portion of Sexually Mature Proglottis of *Dipylidium caninum*; *c*, cirrus; *ov*, ovary; *rs*, seminal receptacle; *t*, testis; *u*, uterus; *v*, vagina; *vt*, vitellarium. × 25. (From Railliet, after Neumann.)

The order Pseudophyllidea is characterized by the presence on the scolex of two poorly developed sucking grooves, which may be in some cases much modified. Of the three sexual pores the uterine orifice lies always on one surface of the proglottis, whereas the two others may be on the same or opposite surface, or on the margin of the proglottis. The sexual organs are generally single, rarely doubled; their development does not transcend the stage of maturity so that no parts degenerate. Eggs usually with cover. Among the twenty-one genera known, only two are of immediate importance here.

Dibothriocephalus Lühe.—Scolex elongated; suckers not powerfully developed; genital organs single; genital pores ventral; uterus in coils in centre of the proglottis producing a characteristic rosette figure (Fig. 1241).

Dibothriocephalus latus Lühe 1899; *Tænia lata* and *T. vulgaris* L. 1748; *Bothriocephalus latus* Bremser 1819; *Dibothrium latum* Dies 1850. Length, 2–9 meters, rarely up to 20 meters, grayish yellow; head elongated oval, 2–3 mm. long, 0.7–1 mm. broad, transversed by two deep lateral grooves. Proglottides, three thousand to four thousand in number, usually broader than long but becoming gradually quadratic. All sexual pores on mid-ventral line, cirrus and vagina opening close together and in front of uterus. Eggs, 68–70 μ by 45 μ. Adult parasitic in small intestine of man, dog, and cat; larva (plerocercoid) in the muscles and among the viscera of various fish.

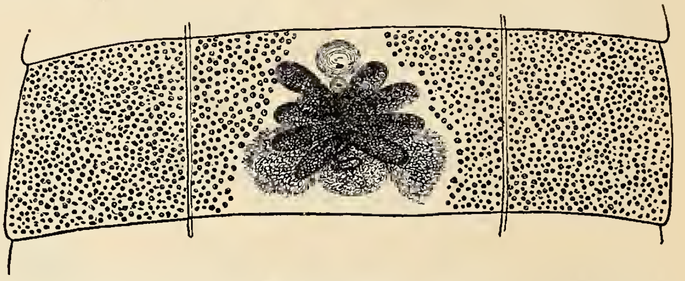
Fig. 1241.—Ventral Aspect of Sexually Mature Proglottis of *Dibothriocephalus latus*, Showing Female Reproductive Organs. (*Cf.* Fig. 1206.) × 12. (After Leuckart.)

Structure.—The longitudinal sucking grooves, characteristic of these forms, occupy in reality the upper and lower face of the head, appearing at the sides in consequence of the torsion of the neck. In external appearance the chain is clearly distinguishable from the other large human tapeworms, *T. saginata* and *T. solium*, by its greater thickness at the middle of the segment. The arrangement of the sexual organs in the proglottis (Fig. 1206) also differs radically from that already described in the genus *Tænia*. The numerous testes occupy a lateral position in the medullary region of the segment, and the vas deferens extends in loops toward the anterior end, terminating in a muscular cirrus pouch with a seminal vesicle. Next the male genital pore lies the orifice of the vagina which passes directly posteriad in the median line, and after forming a receptaculum seminis joins the common yolk duct near the centre of the voluminous shell gland. The vitellaria or yolk glands are racemose structures occupying the cortical layer of the segment in the lateral fields; their numerous ducts converge and ultimately unite into the common yolk duct noted above. The paired ovaries lie one on either side of the shell gland in the posterior region of the proglottis, and the oviduct joins the vagina and the yolk duct in the shell gland. From the union of these ducts originates a canal which expands, and as the uterus, lying in irregular loops ventral to the vas deferens, extends forward to the special uterine orifice, a simple pore in the mid-ventral line a short distance behind the common opening of the cirrus and vagina. In the last proglottides the uterus is often empty of eggs and the genital glands are atrophied.

Development.—Ripe proglottides contain numbers of brownish, elliptical eggs in which may be distinguished the egg cell surrounded by masses of yolk cells. After lying in water several weeks a ciliated onchosphere (Fig. 1209) is hatched out and swims about in the surrounding water. Sometimes this embryo throws off the ciliary covering, but ultimately dies without attaining any further development. How the onchosphere is transformed into a plerocercoid remains still undiscovered. Braun was inclined to believe in the necessity of another intermediate host, and Leuckart and others have endeavored in vain to infect directly with onchospheres the various fish which harbor the larval form. The bladder worm of *Dibothriocephalus latus* was first discovered by Braun in the muscles and viscera of food fish in the Baltic provinces. It is an elongated form known as a plerocercoid (Fig. 1242), and measures 8–30 mm. in length. These larvæ were abundant in fresh fish from Dorpat markets, and living specimens were also obtained from smoked, salted, and frozen fish as well as in the roes of the pike, which salted are eaten raw as caviar. Experimentation on dogs, cats, and man established the connection of this larva with the adult *Dibothriocephalus latus.* Other authors, notably Zschokke in Switzerland (Geneva), have discovered the larvæ in perch, salmon, trout, grayling, and whitefish, and in some instances have determined experimentally their relation to the species of cestode under consideration, confirming fully the discoveries of Braun. In Scandinavia, Lombardy, Switzerland, and Japan the existence of the plerocercoid in various fishes and the consumption of some part of the latter in a raw condition by the native population explain the method of human infection which has been further determined experimentally in specific cases.

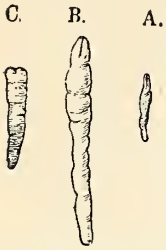

FIG. 1242.—Plerocercoids of *Dibothriocephalus latus* from Pike. *A,* Natural size; *B, C,* with scolex protruded and retracted. ×2. (After Leuckart.)

Once introduced into the human alimentary canal the development of this tapeworm is very rapid, being from 5 to 9 cm. per day in the various cases. Eggs appear in the fæces of man in from twenty-four to thirty days after infection.

Anomalies.—Slender specimens (var. *tenella*) have been recorded, as also some with exceptionally large proglottides. One specimen of the prismatic variety is on record (*cf. T. saginata*) and fenestration of greater or less extent is not rare. Most frequent, however, is the reduplication of the genital pores and organs which Leuckart says he has never failed to find in some proglottis of each specimen examined. Under a separate name (*Bothriocephalus cristatus*) Davaine described a variety which is distinguished from the common by possessing a projecting longitudinal ridge on each flat surface of the head.

Geographical Distribution.—The peculiarities in the distribution of this species are intelligible in the light of its development. It is abundant on the shores of the Baltic, especially the Russian and east Prussian, and around the lakes of French Switzerland, while the territory adjacent to these regions furnishes sporadic cases varying greatly in frequence. Small centres, like Munich (Bavaria), are known to exist, where the origin of the parasite has been attributed to the fish of a certain lake or lake region. In Africa a new centre has been reported recently in the territory around Lake N'gami. In Japan this form is the most abundant of human and canine parasites. Its presence in other regions than those noted has been recorded occasionally, and usually in persons known to have come from the infected regions. Of this type is the record of its presence in Philadelphia made by Leidy. According to Zschokke this species is becoming rarer in Geneva, its frequency having fallen in thirty years from ten to one per cent., and in Paris where it was abundant in the eighteenth century it is no longer autochthonous.

Pathology.—It is sometimes solitary, though several individuals occur together in the majority of cases and nearly one hundred have been recorded from a single host. Evidently its frequence depends upon the habits of the individual in eating raw or poorly cooked fish no less than upon the locality. The effect of the parasite is often unnoticed; in other cases are noted gastric and nervous disturbances, and even pernicious anæmia, which disappear with the removal of the worm. These troubles have been attributed to the production of some toxic substance by the parasite. It should be noted that a self-infection is impossible.

DIBOTHRIOCEPHALUS CORDATUS (Leuckart 1862).—Length, 80 to 115 cm. Head (Fig. 1243); 2 mm. in diameter, flattened cordiform, with deep bothridia on ventral and dorsal surfaces. Segmentation begins directly behind the head; the proglottides, which increase rapidly in width, become mature within 3 cm. The largest proglottides measure 7–8 mm. in length by 3–4 mm. in breadth and number about six hundred. Eggs, with cover, measure 75 μ by 50 μ. Adult parasitic in seal, walrus, dog, and man in Greenland; larva unknown.

The adult is a common parasite in its native land, but records of its presence outside of Greenland are based on errors. However, sporadic cases may occur in those who have become infected while visiting its native home. The intermediate host is doubtless a fish.

DIBOTHRIUM MANSONI Ariola 1900. *Ligula Mansoni* Cobbold; *Bothriocephalus liguloides* Leuckart.; *B. Mansoni* R. Bl.—Adult unknown. Larva a plerocercoid; length, 12 to 20 or even to 35 cm.; breadth, 3–6–12 mm.; flattened without proglottides, but marked by irregular folds. Anterior end enlarged, bearing the head which may be drawn in or evaginated, and on which two faint bothridia are visible. Parasitic in connective tissue of man in Japan and China.

Ten cases of the occurrence of this parasite are reported, one from China and the rest from Japan. It was first found by Manson in an autopsy when a dozen specimens were taken from below the peritoneum, and one free in the peritoneal cavity. Ijima and Murata have described in detail seven cases from Japan; in three the parasite was passed with urine or taken from the urethra, in three cases also it was drawn from tumors of the eye, and in one from a cavity in the subcutaneous connective tissue of the thigh.

Doubtless the larva wanders about in the body of its host, in which, as appears from the details of the last case cited, it may remain active as long as nine years. Ultimately it reaches the surface of the body or of an internal organ (bladder) from which it eventually attains the exterior. Of its origin or its further development nothing is known. No trace of reproductive organs could be found in the specimens studied. In its unusual size and in the presence of longitudinal grooves on the ventral surface, this larva resembles the following species of which the adult alone is known.

DIPLOGONOPORUS Lönnberg 1892; *Krabbea* R. Blanchard 1894.—Genital organs doubled in each proglottis; in other respects identical with those of *Dibothriocephalus.* Genital orifices of each set ventral on either side of the median line of the body, but in the median line of either uterine field.

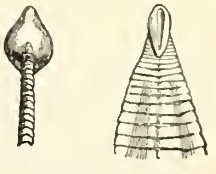

FIG. 1243.—Anterior End of *Dibothriocephalus cordatus* in Lateral and Surface Views. × 5. (After Leuckart.)

DIPLOGONOPORUS GRANDIS Lühe 1899; *Krabbea grandis* R. Blanchard.—Length, 10 meters or more; maximum breadth at anterior end 1.5 mm., in broadest region 25 mm. Proglottides very short, near posterior end only 0.45 mm. in length by 14 to 16 mm. in breadth. Scolex unknown. Genital organs double; two lateral rows of sexual openings on the ventral surface, located in longitudinal grooves with genital sinus in front and orifice of uterus behind it. Eggs brown, thick shelled, 63 μ by 48 to 50 μ in diameter. Found in man in Japan; larva unknown. The first account of this remarkable species was given by Ijima and Kurimoto. It is unique not only in the extreme size manifested, but also in the double genital apparatus which occurs in some species from seals, but save for this species is unknown among human parasites of this group. The sexual organs (Fig. 1244) are characteristically bothriocephaline, but they are found in double sets right and left in each segment, and the orifices open at the bottom of two longitudinal grooves which are characteristic features in the appearance of the worm (Fig. 1245).

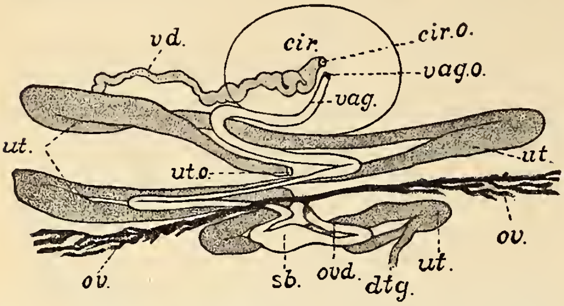

Fig. 1244.—Sinistral Set of Reproductive Organs from Sexually Mature Proglottis of *Diplogonoporus grandis.* × 140. (After Ijima and Kurimoto.)

The authors report that the patient had suffered for five years from dizziness and colic which had finally become so severe as to call for his admission to the hospital at Nagasaki. Here the parasite was removed and even on the following day all the trouble of long standing had entirely disappeared. In view of our rapidly growing intercourse with the East this should be looked for among the unwelcome additions which are sure to be made to our helminthological fauna.

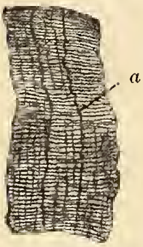

Fig. 1245.—Ventral View of Portion of Chain from *Diplogonoporus grandis.* *a*, Ventral groove. Natural size. (After Ijima and Kurimoto.)

Quite recently Kurimoto has given an account of a second case (also from Japan) in which two specimens of the same parasite were passed. Unfortunately, both scolices were wanting here also. In other particulars the agreement with the original specimen of this species was complete. Anomalies such as fenestration, intercalated proglottides, and those of asymmetrical form were frequent. *Henry B. Ward.*

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CHALYBEATE SPRINGS. — Meriweather County, Georgia.

Post-Office.—Chalybeate Springs. Hotels and cottages.

Access.—Take Southeastern Railroad to Bostwick, thence Talbottom Branch Road to Talbottom, thence 20 miles west to Springs.

These springs were discovered by Mr. Rawlings about 1835, and opened by him for the reception of visitors a few years later. The improvements were of a rude character until about 1850, at which time they were considerably enlarged. With the exception of a few years' interval they have been open to the public ever since. Analysis by Prof. W. J. Land:

One United States Gallon Contains:

Solids.	Grains.
Silicic acid (soluble)	2.83
Iron proto-carbonate	.62
Iron sesqui-carbonate	.17
Lime carbonate	.76
Potassium sulphate	.33
Sodium sulphate	.13
Aluminum sulphate	.43
Sodium chloride	.03
Total	5.30

Carbonic acid gas, 6.55 cubic inches.

The water is a light chalybeate. There are also traces of hydrogen sulphide, carbonate of magnesia, crenate of iron, and a minute trace of nitric acid, lithium, and organic matter. The proportion of soluble salicylic acid is larger than usual. This compound is not used in medicine, but silica is contained in the human body, and may not be without therapeutical value. It is possible that the trace of sulphureted hydrogen also slightly influences the action of the water. It has been recommended in all cases requiring a chalybeate water. The flow is abundant, being about twenty-five gallons per minute. Near by is a sulphur and magnesia spring, but no analysis has been made of the waters. The improvements are extensive, consisting of two hotels and cottages, sufficient to accommodate five hundred guests. Bathing facilities are ample, both hot and cold water being supplied. The climate of this region is of a salubrious character.

James K. Crook.

CHAMÆLIRIUM. See *Unicorn Root, False.*

CHAMIQUEL.—Coalcoman, Michoacan, Mexico. A lukewarm mineral water classified by Dr. Zuniger as a sulphureted calcic water, and containing, according to Forbes, of Coalcoman, carbonic acid, large quantities of lime and magnesia, silica, and traces of copper and iron.

Hirudinea

the range of overextension representing apparently normal flexion. In such cases the leg may be brought to the straight line, but greater flexion is resisted by the retracted tissues, and when the pressure of the hand is removed the leg is drawn back to the deformed position by the contraction of the quadriceps extensor muscle.

Genu recurvatum is not infrequently accompanied by varus or valgus deformity at the knee, more often by the latter, and by laxity of the ligaments. In many instances the patella is absent or is rudimentary and not infrequently deformity is accompanied by malformations or defective development of other parts.

Etiology.—The deformity in cases of simple recurvatum may be explained by an abnormal and fixed position in utero, and in cases seen soon after birth the mechanism is clearly shown by the habitual attitude. The thighs are sharply flexed on the body, the dorsal surfaces of the hyperextended knees are in relation to the abdomen, while the feet may be brought into contact with the face or trunk according to the degree of deformity. The retarded development of the quadriceps extensor muscle explains the rudimentary patella which is often an accompaniment of the deformity.

Treatment.—The treatment of the hyperextended knee is very simple. It consists in massage of the atrophied and contracted muscle, combined with more or less forcible manipulation in the direction of flexion. If, as is often the case, the leg seems to be drawn forward by spasmodic muscular action, the methodical massage should be combined with the use of a simple posterior splint.

In the more extreme cases manual force may be applied under anæsthesia, and the deformity may be overcome at one or several sittings according to the resistance of the contracted parts. The leg is then fixed in a flexed position until the tendency to recurrence has been overcome. When the child begins to walk a light lateral brace may be necessary to insure perfect functional use of the joint, as in many instances laxity of ligaments and muscular weakness may persist for a time.

Rudimentary or Absent Patella.—As has been stated, a rudimentary patella is a frequent complication of genu recurvatum, or of any congenital defect or deformity of the knee or limb that involves imperfect development of the quadriceps extensor muscle. In many cases of this type it is impossible to distinguish the patella during the early months of infancy, but later a minute patella appears that slowly increases to an approximately normal size.

Absence of patella under the same conditions is less frequent, although Potel collected one hundred cases from literature.

Treatment.—The treatment of rudimentary patella is included in the massage and stimulation of the atrophied or rudimentary muscle with which it is usually associated, and the support that the weak or deformed knee may require.

Royal Whitman.

HIPPOCRATIC OATH.—The ancient Greek writings commonly called "The Works of Hippocrates of Cos" were judged even by ancient Greek critics to be really by various authors. The truth of this conclusion is plain to modern scholars. These writings have probably existed as in some sort a collection since the early days of the Alexandrine library near the beginning of the third century B.C.; and the composition of the several writings may safely be referred to the fifth or fourth century. Which of them are truly works of the famous physician whose name they bear is quite uncertain, as no direct contemporary testimony exists. Modern critics can only sift internal evidence, and compare the views of earlier critics, ancient, perhaps, but often naïve or biassed. Many writings in the collection, however, are plainly as old as Hippocrates, if not older. He was born in 460 B.C.; died, probably, in 377 B.C.; and was a worthy of the great period often styled that of Pericles. There is no proof, however, that Hippocrates was ever at Athens, though he was known there; and scarcely anything is known of his life with certainty.

One of the most famous writings of the Hippocratic collection is that entitled "The Oath." It is probably at least as ancient as Hippocrates, but that he composed it can neither be affirmed nor denied. Traces of its widespread influence occur in history; and by means of it modern physicians still hand down the traditions of their calling to those about to receive a medical degree. The ancient words do not accord with the changes wrought by twenty-two centuries in men, beliefs, and manners; but no modern words can be nobler, and the ancient thoughts are vital to the modern oath. The following translation of the Greek original into English is by the present writer:

THE OATH.

I swear by Apollo the Physician, and Æsculapius, and Hygeia, and Panacea, and all the gods and all the goddesses—and I make them my judges—that this mine oath and this my written engagement I will fulfil so far as power and discernment shall be mine.

Him who taught me this art I will esteem even as I do my parents; he shall partake of my livelihood, and, if in want, shall share my goods. I will regard his issue as my brothers, and will teach them this art without fee or written engagement if they shall wish to learn it.

I will give instruction by precept, by discourse, and in all other ways, to my own sons, to those of him who taught me, to disciples bound by written engagement and sworn according to medical law, and to no other person.

So far as power and discernment shall be mine, I will carry out regimen for the benefit of the sick, and will keep them from harm and wrong. To none will I give a deadly drug, even if solicited, nor offer counsel to such an end; likewise to no woman will I give a destructive suppository; but guiltless and hallowed will I keep my life and mine art. I will cut no one whatever for the stone, but will give way to those who work at this practice.

Into whatsoever houses I shall enter I will go for the benefit of the sick, holding aloof from all voluntary wrong and corruption, including venereal acts upon the bodies of females and males whether free or slaves. Whatsoever in my practice or not in my practice I shall see or hear, amid the lives of men, which ought not to be noised abroad—as to this I will keep silence, holding such things unfitting to be spoken.

And now if I shall fulfil this oath and break it not, may the fruits of life and of art be mine, may I be honored of all men for all time; the opposite, if I shall transgress and be forsworn.

The best Greek text (from which the foregoing translation was made) is that of E. Littré, "Œuvres complètes d'Hippocrate" etc., tome 4, Paris, 1844, pp. 628 to 632.

Many commentaries have been published upon the oath. Among these, special mention is deserved by Littré's Argument, *l. c.*, pp. 610 to 625; and by the notes of C. Daremberg, "Œuvres choisies d'Hippocrate," seconde édition, Paris 1855, pp. 1 to 11.

The following matters require discussion, more or less brief:

Hygeia and Panacea were daughters of Æsculapius.

The distinction between "precept" and "discourse" (*παραγγελίης τε καὶ ἀκροήσιος*) has not been explained satisfactorily.

"Suppository" is perhaps as nearly equivalent as possible to the Greek word *πεσσός*, which doubtless means, in the oath, a sort of medicated pledget to be withdrawn after a longer or shorter time. Many formulæ for making such, for various purposes, are given in the Hippocratic collection.

The words "destructive suppository" (*πεσσὸν φθόριον*) refer to abortion. A parallel and fully developed phrase, viz., "a wine destructive to embryos" (*φθόριος ἐμβρύων* οἶνος) occurs in the Materia Medica of the later Greek physician Dioscorides, of the first century A.D. (Lib. v., cap. 77, ed. Sprengel, vol. i., p. 734). Although abortion is abjured without qualification in the oath, there were probably Greek practitioners of the time of Hippocrates who made a distinction similar to the modern one between justifiable and criminal abortion; for methods of emptying the uterus are frequently and quite simply referred to in the Hippocratic collection, though often expressly aimed at embryos styled "dead" or "livid" or "motionless" or "stricken" or "apoplectic."

But there is also good reason to believe that, in Hellas, the accepted line between guilt and innocence in the matter of abortion did not always coincide with that drawn nowadays. The clear recognition of the fact that the early embryo is from the instant of conception a human being, truly alive and possessing the right to live, even before the "quickening,"—this doctrine is entrenched in a maturer knowledge of physiology than the ancients could command. In the ideal State discussed in Plato's dialogue of "The Republic," certain embryos irregularly begotten were to be made away with before birth (Ed. Stephanus, p. 461c). Plato was a younger contemporary of Hippocrates, and Plato's pupil, Aristotle, was born a few years before the death of the great physician, and was himself an Asclepiad, *i.e.*, a physician's son. Aristotle, in his "Politica," expressly recommends abortion in order to limit the number of children, but enjoins the procuring of it "before the advent of sensation and life." The presence of these he formally makes the criterion of "the hallowed" and the reverse in this matter (Politica, vii., cap. 16, ed. Ac. Boruss., p. 1335, b 19 to 26).

In the embryological treatise "On the Nature of the Child" in the Hippocratic collection, the author, who may not have been of Cos, but possibly an adherent of the rival school of Cnidos, describes a certain case as one of abortion at the sixth day deliberately procured by himself. The circumstances are given in detail, and plainly stamp the case as criminal according to modern ideas; but the author relates it without a trace of guilty consciousness, adhering, one may conjecture, to the doctrine of morals set forth by Aristotle ("Hippocrates de Nat. Pueri," § 13, Ed. Littré, vii., p. 488). The following striking passage both shows us "strict constructionists" of the Hippocratic oath nearly five hundred years after the death of Hippocrates, and sets forth explicitly, as current eighteen centuries ago, a view of the morals of abortion closely akin to that of modern physicians. The Greek gynæcologist, Soranus of Ephesus, was a practitioner at Rome under the emperors, not far from the time when Juvenal was scourging its vices with his satires, in the earlier years of the second century A.D. Referring to abortion, Soranus writes:

There is a disagreement; for some reject destructive practices, calling to witness Hippocrates, who says, "I will give nothing whatever destructive," and deeming it the special province of Medicine to guard and preserve what Nature generates. Another party maintains the same view, but makes this distinction, viz.: that the fruit of conception is not to be destroyed at will because of adultery or of care for beauty, but is to be destroyed to avert danger impending at parturition, if the uterus be small and cannot subserve the perfecting of the fruit, or have hard swellings and cracks at its mouth, or if some similar condition prevail. This party says the same thing about preventing conception, and with it I agree. (Translated by the present writer from the Greek of Soranus, Gynæciorum Lib. i., cap. 19, ed. Rose, p. 229).

The abjuration of lithotomy in the oath contains the only mention thereof made in the Hippocratic collection. The ancient practitioners of medicine freely practised operative surgery; and no certain cause can be assigned for their refusal to cut for the stone. It has been shrewdly guessed, however, that the cause lay simply in the formidable dangers of a rude and uncertain procedure.

As the Hippocratic oath still plays a part in medicine worthy of its character and history, it has been thought proper to end this article with one of the modern adaptations. At the annual commencement of Columbia University in the City of New York, the following oath is administered to the graduating class of its College of Physicians and Surgeons:

Candidates for the Degree of Doctor of Medicine:

You do solemnly swear, each man by whatever he holds most sacred:

That you will be loyal to the Profession of Medicine and just and generous to its members;

That you will lead your lives and practise your art in uprightness and honor;

That into whatsoever house you shall enter, it shall be for the good of the sick to the utmost of your power, you holding yourselves far aloof from wrong, from corruption, from the tempting of others to vice;

That you will exercise your art solely for the cure of your patients, and will give no drug, perform no operation, for a criminal purpose, even if solicited; far less suggest it;

That whatsoever you shall see or hear of the lives of men which is not fitting to be spoken, you will keep inviolably secret.

These things do you swear? Let each man bow the head in sign of acquiescence.

And now, if you shall be true to this, your oath, may prosperity and good repute be ever yours; the opposite, if you shall prove yourselves forsworn.

In this oath, the words "that you will be loyal to the Profession of Medicine, and just and generous to its members," are from a formula at one time in use at the above-named medical school; for the rest of the foregoing adaptation the present writer is responsible.

John G. Curtis.

HIRUDINEA.—Among the Annelida or segmented worms the leeches form a well-marked order. The body of the leech is elongated, usually flattened dorso-ventrally, and provided with a prominent terminal or subanal sucker, while many forms possess also an anterior or oral sucker. The bristles all but universally present in annelids are here wanting save in a single genus, and the metamerism of the body presents a poorly marked external aspect although actually highly developed. The rings which appear in external view are mere surface markings, and are variably related to the true somites. Of the latter there are always thirty-four (thirty-five), of which those in the central portion of the body possess the typical number of annuli, while the first few and last few manifest ordinarily a reduction from that number. Prominent papillæ may usually be observed on the dorsal surface in the form of six or eight longitudinal rows; these are metameric sense organs known as sensillæ, and the eyes which vary in number in different forms are anterior units in certain of the rows. The annulus bearing the sensillæ is now generally regarded as the central one of the typical three- or five-ringed somites, and is the only one present in case of those somites manifesting the extreme of reduction. The leeches are hermaphroditic and the two sexual pores lie in the midventral line, the male in front of the female orifice.

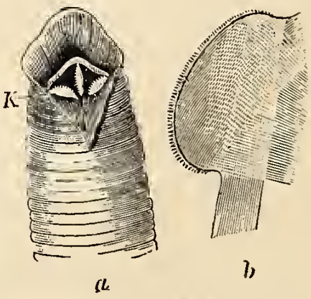

FIG. 2656.—*Hirudo medicinalis*, or European Leech. *a*, Ventral aspect of anterior end, showing an open mouth at the bottom of which the jaws, *K*, are visible; *b*, one of the jaws isolated, showing marginal denticles and muscles. (After Claus.)

The family of the Gnathobdellidæ, or Round-jawed Leeches, is characterized by three saw-toothed jaws in a simple pharynx (Fig. 2656); the typical somite has five annuli. Among the fresh-water leeches (Natantia), which have an eyeless ring between the third and fourth pairs of eyes, only the monostichodont forms (*i.e.*, those with a single row of teeth in each jaw) are important, and of these only two genera need be noticed here.

Hirudo L.—Either one hundred and one or one hundred and two rings with twenty-six metameres between the first pair of eyes and the sucker of which the first six and the last four are abbreviated. Buccal and post-buccal rings fused below; only three annuli in somite XXIII. Each jaw has from fifty to one hundred sharp-pointed teeth. Male genital pore between annuli 30 and 31, female between 35 and 36. First pair of nephridial pores ventral in ring 13, last in ring 93; seventeen in all.

Hirudo medicinalis L.—*Sanguisuga medicinalis* Savigny 1820, *S. officinalis* Savigny 1820, *H. officinalis* Derheims 1825. Length 100 to 200 mm.; breadth 10 to 30 mm. Jaws large, each with 80 to 90 teeth. Color variable, darker above than below, dirty yellowish-brown in tone with tendency to gray or green; at the margin a bright yellow or brown band with black margins; on the back three more or less prominent red longitudinal bands spotted with black (Fig. 2657).

This species is native in Europe, northern Africa and southwestern Asia, but at present is extinct in many regions and obtained by artificial culture or through importation only. Among the very numerous color varieties, as many as sixty-four being recorded by Diesing, two have been recognized as sub-species or varieties:

The Gray Leech, var. *medicinalis s. str.*, back greenish-gray with three russet-red lines on each side, of which the middle one, and often the inner also, shows a black spot on each metamere. Ventral surface greenish-yellow and spotted with black.

The Green Leech, var. *officinalis*, back darker green, often with black pigment more prominent, though red specimens also occur. Ventral surface almost entirely unspotted. A series of intermediate forms makes a distinction even between these two varieties difficult in many cases.

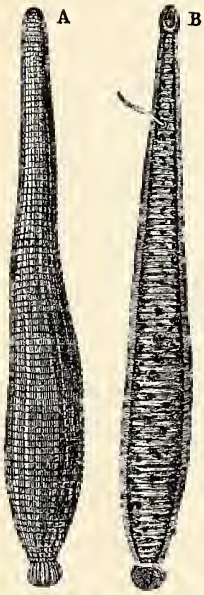

FIG. 2657.—*Hirudo medicinalis*, or European Leech. *A*, Dorsal aspect; *B*, ventral aspect. (After Railliet.)

The leech sucks from four times its volume of blood for the young to three times in an adult, or from 6 to 15 gm. If, however, the sucking leech be cut in two by the shears close behind the pharynx, the blood streams out in pronounced pulsations and, as the sucking action is not interfered with, a stronger or rather longer-continued blood extraction is caused. During the ordinary operation of sucking a leech gives off a large quantity of clear fluid which exudes from the skin in drops. It is not blood serum, as often supposed, but the secretion of the nephridial canals. While this exudation ceases at the end of ten days, the assimilation of the stomach contents of the leech demands from twelve to eighteen months. At the end of two months, however, the animal manifests willingness to bite, but its full appetite is not yet restored. On the other hand, the leech can fast for two years or more and may be kept indefinitely without food in suitable leech jars. A fast of from six to eight months is necessary before re-employment; but the latter is not advisable. Before the third year of their growth leeches are not used for medicinal purposes, and from eighteen to twenty years has been put as the probable length of life. For the method of using leeches, see *Blood-letting.*

At one time the enormous demand for leeches reached, for example, 7,000,000 per year in London alone, but in recent years their use for therapeutic purposes has greatly diminished, no doubt largely as the result of occasional fatal cases and in spite of certain evident advantages for local affections. Fatal bleeding has been known where the bite opened a large vessel (*vena cruralis* or *jugularis*), or in internal organs where the leech, by careless application at the nasal fossæ, vagina, or rectum, has penetrated or been drawn too deeply into the organ. In order to guard against this leeches should be fastened in such cases by a thread passed through the middle of the posterior sucker. Several authors have investigated the reputed transmission of disease, particularly bacterial, by leeches, but uniformly with negative results. So far as bacteria are concerned, the species studied were rapidly digested in the stomach of the leech, and the entrance into the wound of such as may be upon the lips at the start appears difficult under the circumstances of the blood flow.

Where native, these, like other large leeches, attack men and animals invading swamps and pools, and in recorded instances with fatal results to children or young animals.

Hirudo troctina Johnson 1816, often confused with the medicinal leech, is distinguishable by its smaller size, 80 to 100 mm. in length by 12 to 18 mm. in breadth, and especially by the scantier number of teeth, about seventy, in each jaw. It is native in northern Africa and Spain, perhaps also Italy and Sicily, and is exported in large numbers to France, England, and America. In power to extract blood it is much inferior to *H. medicinalis.*

Hirudo nipponica Whitman 1886, also smaller in size than *H. medicinalis*, is common about Tokyo, Japan, and in other parts of the island. Its habits and use conform closely to those of the continental species. Other species of similar habit are reported from different regions of the Orient; they are, however, only poorly known.

The genus *Limnatis* may be distinguished from *Hirudo* by the papillæ on the jaws and by the ventral furrow traversing the entire length of the anterior lip of the oral sucker. One species, *Limnatis nilotica* Sav., demands brief notice. It is native in the circummediterranean region, and in some places is so abundant as to become a veritable pest. Especially the young, described by Moquin-Tandon as *Sanguisuga ægyptiaca*, are often swallowed accidentally in drinking and may remain for a long time fixed in pharynx, choanæ, œsophagus, trachea, or even stomach. The species plays accordingly an important rôle in diseases of man and domestic animals in northern Africa during the hot season. European soldiers in garrison, and even natives, in spite of their precautions, suffer from the leech, which evokes by its presence both local and general symptoms of serious character if assistance is not speedily afforded. With the removal of the worms rapid and complete healing of the wounds and disappearance of secondary symptoms occur almost immediately and without exception. The removal may be accomplished by instruments from those organs where the leech can be seen; in deeper locations copious application of salt water is said to be efficacious. This leech can pierce only the mucous membranes of higher animals, and its inability to penetrate the external skin, even of children, has often been demonstrated. Other species of this genus have a more powerful bite, and are used especially in the East for medicinal purposes, even though they take up less than half as much blood as *Hirudo medicinalis*. In this country *Macrobdella decora*, one of the large native leeches, is employed in some places for blood-letting; it may be recognized by the following description:

Macrobdella Verrill 1872. Cephalic lobe smaller than in *Hirudo*. Annuli 103; at least four in somite XXIII.

Neither buccal nor post-buccal annuli united on the ventral side. Both genital orifices in somite XI., and behind them a group of prominent copulatory glands.

Macrobdella decora Verrill.—*Hirudo decora* Say 1824, *H. decora* Leidy 1868. Jaws with about sixty-five teeth, copulatory glands opening by four pores in a quadrate figure on the last annulus of XIII. and the first two of XIV. The first annulus of XXVI. is divided marginally and sometimes also dorsally into two annuli.

This species is widely diffused in fresh waters of the United States, having been reported from Maine to Minnesota and from Pennsylvania to Kansas. It is frequently used instead of imported leeches by physicians and is said to be equally efficacious, although its capacity is somewhat smaller, only about 5 gm. It is so powerful, however, that serious results have followed its attacks upon the legs of children wading in its haunts.

Among the land leeches which form a special section, Reptantia, of this family, and are distinguished by the absence of an eyeless ring between the third and fourth pair of eyes, a few forms deserve brief mention.

Hæmadipsa Tennent. Body almost round, sucker separated only by a slight constriction. Near the sucker auriculæ with the pores of the last pairs of nephridia. Typical metamere with five annuli.

Hæmadipsa zeylanica Moq.-Tand.—*H. japonica* Whitman. Length 20 mm., or in extended form 60 mm., diameter of body behind 6 mm., in front 2 mm.; sucker 5 to 7 mm. in diameter. Annuli ninety-seven; male genital pore between annuli 30 and 31, female between 35 and 36. In each jaw ninety incurved teeth.

The animal, when gorged, has the form of a flask of about 10 mm. in diameter at its largest part, while the neck measures only 2 or 3 mm. in thickness. The color is exceedingly variable, and yet five or six varieties may be recognized, one of which, var. *japonica* Whitman, known in Japan as the mountain leech, is common in the entire Indomalayan region, China, and Japan. It has long been known on the island of Ceylon, where it forms a veritable pest to natives and Europeans alike. The leeches appear in immense swarms, particularly in moist regions and during the rainy season, and at all levels from the coast up to 4,000 feet, although they occur even as high as 15,000 feet in the Himalayas. During the dry season they hibernate in the earth; at other times they live in moss among stones and on shrubs and trees. The approach of large animals brings them out in myriads; they move with surprising activity, and springing on the unfortunate passer-by they suck often for hours before falling off. No clothing is close enough to protect man from their attacks, and during army manœuvres they have inflicted large losses on European troops, attacking the soldiers even when asleep. Accounts of travel in Ceylon abound in narratives of the ferocity of these pests, and recent writers from the Philippines comment on their activity in that country in equally forcible terms. It is probably this species, and very likely the variety *japonica*, which is reported by Blanchard as abundant in the Philippines, to which the trouble is due, although other species of *Hæmodipsa* manifest, no doubt, similar habits of life.

The bite is not poisonous, as often maintained, but the large number of wounds and careless treatment afford abundant opportunity for secondary infection of a serious character. Among the natives of Ceylon one may see many deformities induced by these leeches, which are accordingly feared more than serpents and carnivores.

An allied form, *Phytobdella Meyeri* R. Bl., is also recorded from Luzon.

The family of the Rhynchobdellidæ, or proboscis leeches, is characterized by a protrusible pharynx, while the typical metamere consists of three annuli and jaws are lacking. Few of these forms are able to penetrate the human skin, but among those of sufficient power are especially American forms, which appear as occasional parasites of man and in some regions are used for therapeutic purposes. The two species of importance are both members of the following genus, which is restricted to the warmer regions of the American continent:

Liostoma Wagler 1831—*Hæmenteria* de Fil. 1849. Body broad and flattened; back covered with many prominent papillæ; the first and third ring of each somite, from VI. to XXII. inclusive, split on the ventral surface so that on the ventral surface the space occupied by five pseudo-annuli corresponds to that occupied by the three adjoining dorsal annuli. Male genital pore between annuli 26 and 27, female between 28 and 29. Two pairs of eyes so closely set that they appear as a single pair.

Liostoma Ghilianii R. Bl.—*Hæmenteria Ghilianii* de Fil. 1849. Length of alcoholic specimen 190 mm., breadth 100 mm., corresponding to a probable length while living of 350 to 400 mm. Annuli seventy, together with three preocular; the first seven annuli form the oral sucker.

This giant form inhabits the basin of the Amazon and the swampy regions of Guiana. Blanchard reports that it attacks horses and cattle, and a few individuals are sufficient to kill even a full-grown animal.

Liostoma coccineum Wagler 1831—*Hæmenteria officinalis* de Fil. 1849, *H. mexicana* de Fil. 1849, *Glossiphonia granulosa* Jimenez 1865. Length 80 mm., breadth 22 mm. Annuli seventy, with two preocular; the first six annuli form the oral sucker (Fig. 2658).

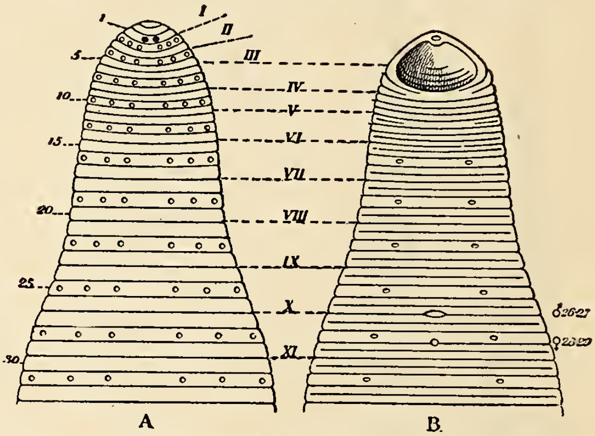

FIG. 2658.—*Liostoma coccineum*, or Mexican Leech. Diagrammatic view of anterior somites, *A*, from dorsal surface with eyes and sensillæ, *B*, from ventral with nephridial and sexual pores. (Modified from Blanchard.)

The range of this species extends from Mexico to Paraguay through Central and South America. In Mexico it is universally used as the medicinal leech. In some instances, however, its bite appears to be accompanied by serious results. There are noted almost immediately a feeling of general lassitude and an unpleasant itching and twitching, succeeded soon by general urticaria, and in a short time apoplectic symptoms are manifested; but cases occur in which the cerebral congestion or the urticaria is wanting. Most authors incline now to the belief that these symptoms are due to the salivary secretion poured into the bite by the leech, and yet it seems also clear that some predisposition on the part of the individual is also a prerequisite. Brandes suggests that the symptoms of poisoning are manifested only in persons exhibiting hyperæsthesia, and attributes the rare cases of serious illness following the application of *Hirudo medicinalis* in Europe to the same sensitive constitution. (Compare in this connection the effects produced by the bite of *Argas*, as reported by Brandes and noted in the article *Arachnida*, Vol. I., p. 437.)

In spite of these accidents this is actually the only species used for medicinal purposes in Mexico, sufficient evidence of its generally satisfactory character. In some provinces (Guadalajara) the leech is regularly cut in two after it has taken hold in order to measure definitely the quantity of blood extracted. *Henry B. Ward.*

Principal Articles Used.

Blanchard, R.: Révision des Hirudinées du Musée de Turin. Boll. Mus. Zool. Torino; vol. viii., No. 145, 1893.—Révision des Hirudinées du Musée de Dresde. Abh. u. Ber. k. zool. u. anthrop. Mus. Dresden, 1892–93, No. 4, 1894.

Castle, W. E.: The Metamerism of the Hirudinea. Proc. Am. Acad., vol. xxxv., No. 15, 1900.

Leuckart, R.: Die Parasiten des Menschen, etc., zweite Aufl., Lief. 5, 1894; Lief. 6 (Nach dem Tode des Verf. bearb. v. Dr. G. Brandes), 1901.

Verrill, A. E.: Synopsis of the North American Fresh-Water Leeches. Report United States Fish Com. for 1872–73, p. 666, 1874.

Whitman, C. O.: The Leeches of Japan. Quar. Jour. Mic. Sci., vol. xxvi., p. 317, 1886.

Also shorter papers by the same authors, Leidy, J. P. Moore, and others.

HISTOLOGICAL TECHNIQUE.—Methods of Studying Living and Fresh Tissue.—For observations on living tissue, we now make use of the cold-blooded animals almost exclusively; and, on account of the convenience, use the tails of amphibian larvæ, and small fishes and frogs. For holding these small animals, while under observation, the larva holder of Schulzer (Fig. 2659) will be found very convenient. The head of the animal is placed under the edge, *a*, the tail is spread out on the bevelled plate, *b*, and covered with a cover-glass. The cell holds sufficient water to cover the animal. To keep the animal quiet, we wrap it loosely in a piece of cloth, leaving the gills free, or add a few drops of ether to the water. If the observations are to be continued for any length of time, provision must be made for the renewal of the water. This can be accomplished by any of the usual methods of irrigation.

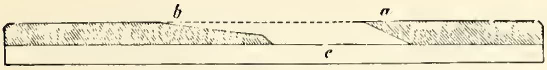

Fig. 2659.—Schulzer's Larva Holder.

For observations on the frog, it is necessary to paralyze the animal with curare. A slight nick is made in the skin over the posterior part of the head, and two or three drops of a one-twentieth-per-cent. solution of curare* is injected into the dorsal lymph sac by means of a long, slender pipette introduced through the above nick. The exact amount of curare to be used will depend upon its quality and the size of the animal, and can be determined only by experiment. In the course of a few hours the animal will become completely paralyzed, while the vegetative functions continue, the necessary amount of oxygen being supplied by cutaneous respiration.

We utilize for these observations:

1. *The Web.*—The advantage of this part of the animal is that we do not inflict any injury, consequently we are not likely to meet with any disturbances of the vital processes; but, on account of it not being very transparent, it is inferior to other parts. A frog poor in pigment should be selected, and after being wrapped in a moist cloth it is laid on an oblong sheet of cork, in one end of which a hole, at least 15 mm. in diameter, is made; at the edges of this hole four or five pins are stuck, to which bits of soft string attached to the toes are tied, spreading the web out over the hole. The cork is now placed on the stage of the microscope, and the web is moistened at intervals to prevent its drying.

2. *The Tongue.*—For observations on this and other organs of the animal, Professor Thoma has invented a series of frog plates, which are shown in Fig. 2660. The one in the centre of the figure is for the tongue; that on the left for the mesentery; that on the right for the lung and bladder. These plates consist of a bed plate, *a*, of brass, covered by a thin sheet of hard rubber. At *B* is an opening, which varies in the different plates, covered with a thick glass plate on which the organ to be examined is placed. At some distance from this glass plate runs the brass rim, *c*, *c*, *c*, 7 mm. high, which by a proper inclination conveys the irrigating fluid, as it flows off the organ, to the tubes, *d*, *d*, to which are attached rubber tubes leading to a vessel for receiving the waste fluid. The supports, *t*, are for holding the irrigating cannula, *g*. They are pivoted to the plate, and move on a perpendicular axis; to the upper end is attached a short split tube, which is tightened by a small screw; this is connected with the support by a hinged joint, allowing it to be moved on a horizontal axis. In this tube is placed the glass irrigation cannula, *g*. It will be noticed that in the tongue and mesentery plates two supports are provided. This is to allow of the use of two cannulæ, one for irrigating the upper, and the other the under, surface of the organ. At *e* is a perpendicular rod for supporting the ring holding the cover-glass. At each side of the plates (in the tongue plate it is at the end) is a notched support, *k*, for holding the rubber tube attached to the cannulæ introduced into the different organs for inflation, etc. Between the rim, *c*, *c*, *c*, and the plate, *B*, bits of cork are wedged for pinning out the organs.

For examining the tongue, the animal is placed on the plate belly down, and the nose is brought close to the edge of the glass plate; the tongue is drawn out over the plate, and fastened to the bits of cork by pins which are cut off short.

3. *The Mesentery.*—Male frogs are to be used, so that the examiner may not be embarrassed with the ovaries. An incision is made through the skin, on the side, from the pelvis nearly to the axilla. After all hemorrhage has ceased, the abdominal cavity is opened by an incision of 10 to 20 mm. in length; a coil of intestine is drawn out carefully over the glass plate so that it will fall upon the bits of cork, to which it is pinned, leaving the mesentery spread out in a thin layer on the glass plate.

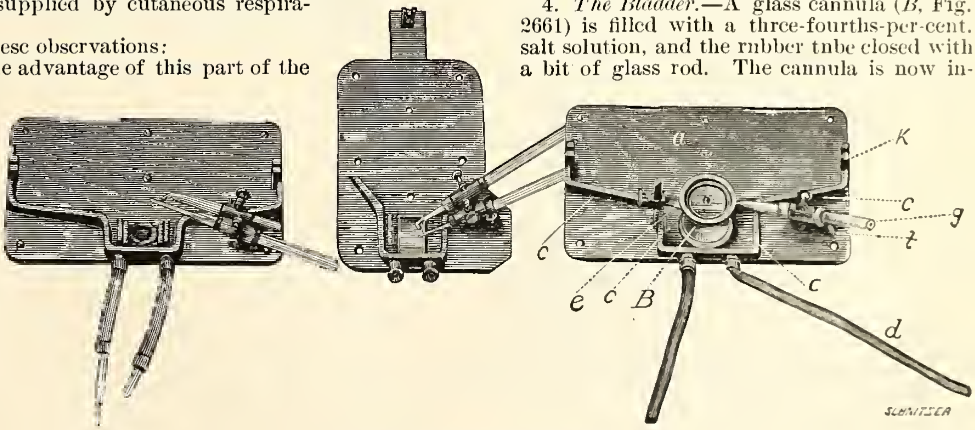

Fig. 2660.—Thoma's Frog Plates.

4. *The Bladder.*—A glass cannula (*B*, Fig. 2661) is filled with a three-fourths-per-cent. salt solution, and the rubber tube closed with a bit of glass rod. The cannula is now inserted into the cloaca, and directed forward into the bladder; it is held in place by a thread passed through the skin over the sacrum and tied around the cannula. An incision, similar to the one for the mesentery, is made in the side of the animal. The glass rod is removed from the rubber tube, and the latter is raised slightly so

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* S. H. Gage recommends the following solution: Curare, 0.2 gm.; ninety-five-per-cent. alcohol, 20 c.c.; water, 20 c.c. Grind up the curare in a mortar with the water and alcohol. Do not filter.

as to cause the fluid to flow into the bladder, distending it. The animal is now placed on the frog plate, and by gentle manipulation with the handle of a scalpel the distended organ is brought upon the glass plate and further distended if necessary; the glass rod is now replaced in the rubber tube, and the latter fixed in the support (*k*, Fig. 2660). The animal is covered with a bit of moistened filter paper, and the frog plate is placed on the microscope.

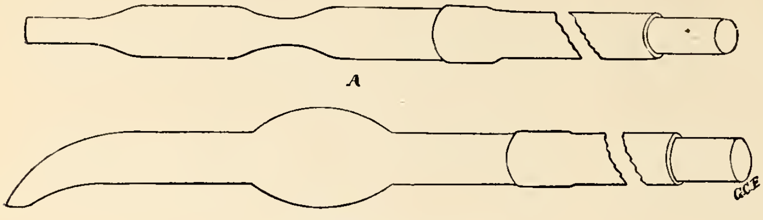

Fig. 2661.—Inflation Cannulæ.

5. *The Lung.*—The cannula (*A*, Fig. 2661) is introduced through the epiglottis, and held in place by a thread passed through the nose and tied around the constriction of the cannula. An incision, carried well into the axilla, is made through the skin on the side of the animal, and when all hemorrhage has ceased the thoracic cavity is opened. The operator should now remove the bit of glass rod from the end of the rubber tube attached to the cannula, and gently blow into the same, when the distended lung will be forced through the incision. The animal is placed on the frog plate, and the distended lung brought upon the plate *B*. In Fig. 2662 is shown the arrangement of the frog plate on the microscope, and the irrigating bottle. The stage of the microscope is to be inclined so as to cause the irrigating fluid to flow away. The bottle attached to the ring stand, filled with a three-fourths-per-cent. salt solution, is closed tightly with a rubber cork, through which pass two glass tubes. To one is attached a rubber tube, which is connected with the glass cannula (*g*, Fig. 2660) and conveys the irrigating fluid. The other is for regulating the pressure, which can be varied by raising or lowering the tube. The flow from the end of the irrigating cannula should be by drops, at short intervals, and is regulated by the pressure in the bottle, the size of the opening in the point of the cannula, and, if necessary, by a spring clip placed on the rubber supply-tube.

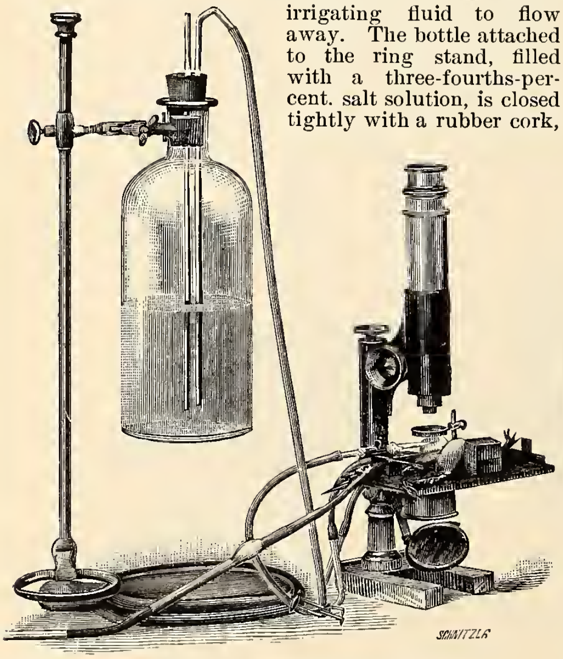

Fig. 2662.—Frog Plate and Irrigating Apparatus.

Fresh tissues are to be examined in the fluid that bathes them during life, or in a fluid that will change them but little if at all. Such fluids are known as indifferent fluids, and resemble in composition the natural fluids of the body. They are as follows:

Aqueous Humor of the Eye.—Obtained by puncturing the cornea of a recently killed animal, and allowing the aqueous humor to escape.

Blood Serum.—The blood of a recently killed animal is poured into a tall glass cylinder and allowed to coagulate. After coagulation has taken place, the upper margin of the clot is separated from the sides of the vessel, to permit it to sink; the vessel is allowed to stand for twenty-four hours, and the clear serum is then drawn off with a siphon, care being taken not to disturb the clot.

Iodized Serum.—Prepared by adding to every 1,000 c.c. of blood serum, obtained as above, 10 c.c. of tincture of iodine. This fluid alters the tissues slightly and stains them yellow. Instead of blood serum, amniotic or pericardial fluid may be used, but it must be absolutely fresh.

Artificial Serum.—This is to be used only when the natural serous fluids cannot be obtained. It is prepared by dissolving 2 gm. of sodium chloride and 28 gm. of egg albumen in 250 c.c. of distilled water, and adding 2.3 c.c. of tincture of iodine; the solution is then filtered.

Salt Solution (three-fourths per cent.).—Made by dissolving 7.5 gm. of perfectly dry, chemically pure sodium chloride in 1,000 c.c. of distilled water. This solution alters fresh tissues but slightly.

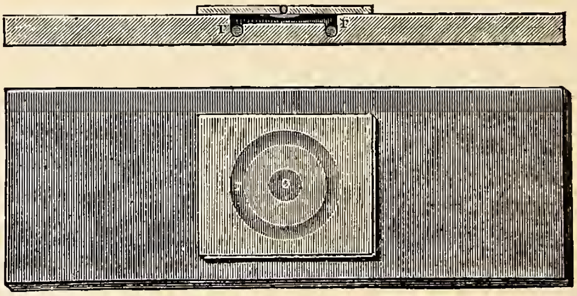

Fig. 2663.—Moist Chamber.

Fresh, thin membranes can be examined in one of the above solutions without any previous preparation. Bits of organs, fibres, etc., are to be teased on a slide, in a drop of one of the indifferent solutions, or sections can be made by the freezing microtome.

In observations on fresh tissue it is necessary to prevent evaporation, and in most cases pressure. The first can be prevented by painting a ring around the cover with oil or vaseline; the latter by placing a hair between the cover and slide; or we may use the moist chamber.

In Fig. 2663 is shown a moist chamber. In the centre of a thick glass slide is cut a cavity, around the circumference of which is a groove (*rr*). The latter is filled with water; the specimen is placed on the cover-glass (*o*), or in the middle of the cavity.

Methods of Applying Reagents.—*Application of Fluids, Irrigation.*—A drop of the reagent is placed on the slide in contact with the edge of the cover-glass, and on the opposite side of the cover a bit of filter paper. The latter sucks out the fluid, which is replaced by the reagent flowing in on the other side. This process of ir-

Mosquitoes.

Prognosis.—In cases of moderate extent and severity the prognosis is usually fairly favorable. In the majority of cases, after a duration of some months, or it may be two or three years, the skin gradually resumes its normal aspect. When, however, marked atrophy has taken place with adhesion to the deeper structures, forming scar-like patches, the prognosis is extremely unfavorable.

Treatment.—Treatment is rather unsatisfactory. Internally such remedies as cod-liver oil, arsenic, quinine, and iron may be administered with the view of improving the patient's general health. Thyroid extract has been given with asserted good results in a small number of cases. Locally, frictions with bland oils and fats are useful, and so also are mild galvanic currents applied, as Crocker suggests, in the neighborhood of, rather than directly to, the patches, to avoid any possible irritant effect. Brocq recommends electrolysis, employed as in the removal of hairs. The needle should be inserted in every portion of the patch, the current used varying from 8 to 15 milliampères, and the needle should be allowed to remain fifteen seconds at each puncture. Between the sittings mercurial plaster is to be applied. Hebra has obtained good results from intramuscular injections of a fifteen-per-cent. alcoholic solution of thiosinamin, half a Pravaz syringeful of the solution being injected every second day. *Milton B. Hartzell.*

MORRISON SPRINGS.—Jefferson County, Colorado.

Post-Office.—Morrison. Hotel recently built.

Access.—From Denver viâ Denver, Gunnison, and Leadville Railroad. Morrison Springs are located fourteen miles southwest from Denver, in the basin of Bear Creek and just within the Rocky Mountain foothills at an altitude of six thousand feet above the sea level. No complete quantitative analysis of the waters seems to have been made, but Dr. W. C. McNeal, of Morrison, furnishes us the following report of a partial qualitative examination:

Sulphureted hydrogen.
Calcium bicarbonate.
Manganese.
Sulphuric acid } Doubtless in
Arsenious acid } combination.
Iron.
Magnesium sulphate (forty grains per gallon).
Potassium (trace).
Temperature of water, 80° F.

This incomplete analysis would indicate that the waters possess tonic, laxative, and alterative properties. They are recommended in renal, digestive, skin, and rheumatic affections, and in chronic syphilis. *James K. Crook.*

MORTALITY. See *Vital Statistics.*

MORVAN'S DISEASE; ANALGIC PANARITIUM.—This curious and extraordinarily rare disease was first described by Morvan, of Brittany, in 1883. In applying the name analgic panaritium, or "painless whitlows," Morvan was obviously more influenced by the salient clinical feature of the disease than by any consideration for its underlying pathology. Viewed in the light of the more critical tendencies of recent years, the desirability of retaining it as a clinical entity, to the burden of an already overcrowded neurological nosology, seems more than doubtful.

The opportunities for investigating the disease, even in the services of large hospitals, are so meagre that little or no satisfactory advance has been made in our exact understanding of its genesis and morbid sub-structure. It appears to consist of a syringomyelic condition—or of the associated gliomatosis—plus a peripheral neuritis.

In the few cases in which a microscopic examination of the cord has been made, the connective-tissue overgrowth appeared in the posterior part of the gray matter and in the posterior columns.

It is practically certain that syringomyelia takes its origin in a developmental defect. As the primary morbid condition of the disease under consideration is analogous to that of syringomyelia in all essential details, it seems to the writer much more reasonable to regard the extra feature of Morvan's disease, the peripheral neuritis, of identical origin. This point of view makes the two morbid processes practically alike in all respects except topography, and the doubt arises as to whether this single feature of dissimilarity is sufficient to establish Morvan's disease on the plane of a clinical entity. Repeated observations of the apparent fortuitousness of the morbid distribution in cases of other developmental defects should tend, by analogy, to reduce the present distinguishing features of syringomyelia and what we now term Morvan's disease to the vanishing point, and such a result is desirable for obvious reasons.

As the clinical features of the two diseases now stand, there is nothing upon which we may rely absolutely for differentiation between them. Both are apt to give the first clinical manifestations of their presence in the first half of adult life, and both are alleged to follow some traumatism or to arise in consequence of abuse of function. How important local traumatism may be in the production of Morvan's disease it is difficult to say, owing to the natural rarity of the affection. It probably has about as much etiologic value, however, as that other frequently alleged causative agent in nervous diseases—exposure to cold and wet.

In Morvan's disease the symptoms begin as a rule in the upper extremities. Of these the most striking are the whitlows, which are usually, though not invariably, painless, owing to the loss of all forms of sensation preceding them. With the whitlows there may be recurring ulcerations on various parts of the fingers. These ulcers are deep and not unlike the perforating variety observed in tabes. They are accompanied by cracks in the skin, and the nails shrivel and split. Although the occurrence of the whitlows is the striking feature of the disease, it is not the most important or serious. As has been said, they occur as a rule subsequently to the abolition of all forms of sensation, but they have important precursors in the form of muscular weakness and wasting in the hands and forearms. Although the trophic mischief is practically limited to the hands, and the muscular wasting does not go above the forearms, the sensory loss may involve the entire arms, parts of the trunk, and even the face. Sufficient vaso-motor derangement to cause lividity and pallor of the skin often precedes and accompanies the nutritional disturbance. An affection of the shoulder-joint has been noted. When the ulcerations of the fingers involve the terminal phalanges, the latter may be entirely destroyed. The electrical irritability of the nerves involved in the affected parts pursues variations, as the disease progresses, similar to those observed in the progressive atrophies of spinal origin, a gradually increasing quantitative loss, followed by inversion of the formula. The feet are rarely the seat of the painless ulceration; although the legs may be weak and the knee-jerks exaggerated, owing probably to the partial implication of the nutritional arteries of the lateral columns in the overgrowth of tissue. The course of the disease is extremely slow, extending over many years. In certain cases it has appeared to be arrested.

In the matter of differential diagnosis there are no particular difficulties except in regard to syringomyelia. Here, in the opinion of the writer, there is no absolute distinction. For certain authorities the retention of tactile sensibility and the absence of the whitlows are sufficient to rule out Morvan's disease in a doubtful case. In Raynaud's disease the vaso-motor disturbance is paramount and the loss of sensibility, when it exists, is not alike in kind or degree. In sclerodactyla there are no sensory loss and no tendency to destructive ulceration of the finger ends. In anæsthetic leprosy there are no ulcerations whatever, while there is a tendency to pigmentary deposit in the skin areas involved.

Owing to the nature of the malady, the question of treatment is easily settled. No drugs are specifically indicated. Even symptomatic treatment is of little importance because of the practically painless course which the disease pursues. Iron, arsenic, and strychnine are among the drugs used, but it is more than doubtful if they have exerted other than a general effect.

Joseph William Courtney.

MOSQUITOES IN RELATION TO HUMAN PATHOLOGY.—The special importance of the mosquito as an agent in the transmission of disease has been thoroughly demonstrated by recent discoveries, a brief synopsis of which may be given as an introduction to the subject.

History.—In 1880 Manson, by establishing the connection of mosquitoes with elephantiasis, gave the first demonstration of their culpability in spreading disease. It was the same year (1880) that Laveran discovered the intraglobular parasites now universally acknowledged as the cause of malaria. The transference of these hæmatozoa from one host to another by means of mosquitoes was conjectured as early as 1883 by King and in the following year by Koch and Laveran; but was first actually demonstrated by Ross, in a series of experiments between 1895 and 1899; these facts have been abundantly confirmed by many subsequent investigators. In 1897 MacCallum first observed the sexual phase in the allied avian hæmatozoa, and the further elucidation of the life history of the parasite was brought about by contributions of Ross, Bastianelli, Bignami, Grassi, and others, while unimpeachable evidence of the agency of the mosquito in carrying the disease was furnished by the positive infection experiments of Manson, who imported from Rome tertian infected *Anopheles*, which evoked the disease in those whom they were permitted to bite in London.

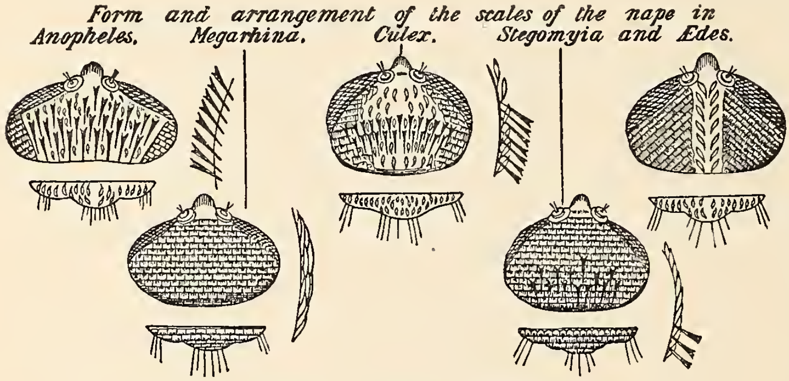
Form and arrangement of the scales of the nape in
Anopheles, Megarhina, Culex, Stegomyia and Ædes.

Fig. 3363.—Graphic Key to Scale Arrangement of Leading Genera. (After Giles.)

The connection of the mosquito with yellow fever, conjectured by Finlay of Havana as early as 1881, waited until 1900 for its experimental demonstration in the investigations of the Yellow Fever Commission, consisting of Drs. Reed, Carroll, Lazear, and Agramonte, in the course of which two members of the Commission acquired the disease and one, Dr. Lazear, succumbed to it.

Kinds of Mosquitoes.—It is necessary now to consider the various types of mosquitoes before taking up more specifically their relations to disease. In all about three hundred species of mosquitoes have been described, of which only thirty-six species have been recorded in North America. Of these five belong to the genus *Anopheles*, three to *Stegomyia*, and no less than eighteen to *Culex*. It would be impossible within the limits of an article even to outline the complete classification of the group, but some of the most important facts may be stated briefly. The order and family have been sufficiently characterized by Professor Osborn (see *Insects*). It is extremely uniform in character, and only recently has Theobald found a basis for subdivision in the form and arrangement of the scales on the body and wings. His classification with some additions suggested by Giles is followed here. The sub-families are distinguished as follows:

Section A. Proboscis formed for piercing.

I. Brilliantly colored insects with a very long, curved proboscis.

(*a*) Palpi, about as long as the proboscis in both sexes (*Megarhina*); or long in male, shorter in female (*Toxorhynchites*). *Megarhinina.*

II. Dull-tinted insects with straight proboscis.

(*b*) Palpi about as long as the proboscis in both sexes: those of the male clubbed at the end, those of the female linear. *Anophelina.*

(*c*) Palpi about the length of the proboscis in the male but much shorter in the female, being here usually very short. *Culicina.*

(*d*) Palpi very short in both sexes. *Ædomina.*

Section B. Mouth parts not formed for piercing, there being no true proboscis. Palpi small. *Corethrina.*

For the determination of the genera the form and arrangement of the scales, which are all-important, are shown diagrammatically in the figure (Fig. 3363). So far as the species are concerned, it is impracticable to make more than a preliminary determination without referring to a monograph, and there will be mentioned only a few of the more important forms, in those genera which are now known to be responsible for the transmission of disease. A few hints as to methods of collecting and examining will doubtless be useful to the practitioner. The adult mosquitoes are very delicate, so that the parts are easily broken and the arrangement of the scales easily obscured by rough handling. The female may be readily caught on the hand or arm when biting, or even on the wall of a room, by inverting an ordinary vial over it; once trapped a whiff of tobacco smoke or a drop of chloroform will kill it immediately and leave the specimen in good condition for examination or transportation on cotton in a pill box. A good killing vial may be made by confining a small piece of cyanide of potassium at the bottom of a shell vial by a disc of blotting paper cut to fit the vial. After it has been inverted over the mosquito, the cork may be slipped into the mouth of the vial and the insect succumbs almost instantly and without damage. Mosquitoes may be mounted dry on pieces of thin card or cork, but should not be enclosed in balsam as this destroys colors and renders identification difficult. Most of the characters can be determined with a triplet; all with the low power of a compound microscope.

For collecting larvæ, which are often difficult to distinguish against the dark background in a pool, a white cup is useful; or a coffee strainer may be drawn through the vegetation at the margin of a pond or stream and the material obtained may be examined more carefully in a cup of water or on a white plate. Larvæ may be bred in jars, which should be covered with mosquito netting to prevent the escape of the adults when they emerge, while the latter may be kept in frames of netting, but should be provided with a little water and pieces of banana or dates on which they feed. If desired larvæ may also be preserved in dilute formalin or in alcohol. Further data may be found in any of the manuals cited.

Anopheles Meigen (1818).

Head with both flat and narrow curved scales, but mainly covered with large upright forked scales; palpi long in both sexes, usually about the length of the proboscis, four-jointed in the female, three-jointed in the male, in which the last two joints are short and thick; constrictions at the base make the palpi possess apparently one or two extra joints in each sex. Antennæ, fourteen-jointed, filiform, pilose in the female, fifteen-jointed and plumose in the male.

Thorax sometimes nude on the dorsum, usually with narrow curved or small spindle-shaped flat scales. Abdomen generally pilose, but sometimes with a few scales and rarely with many. Wings covered with small scales of normal form or inflated, with the first submarginal cell longer and narrower than the second posterior cell; both the second and third long veins run past the cross veins into the basal cells, a very marked characteristic.

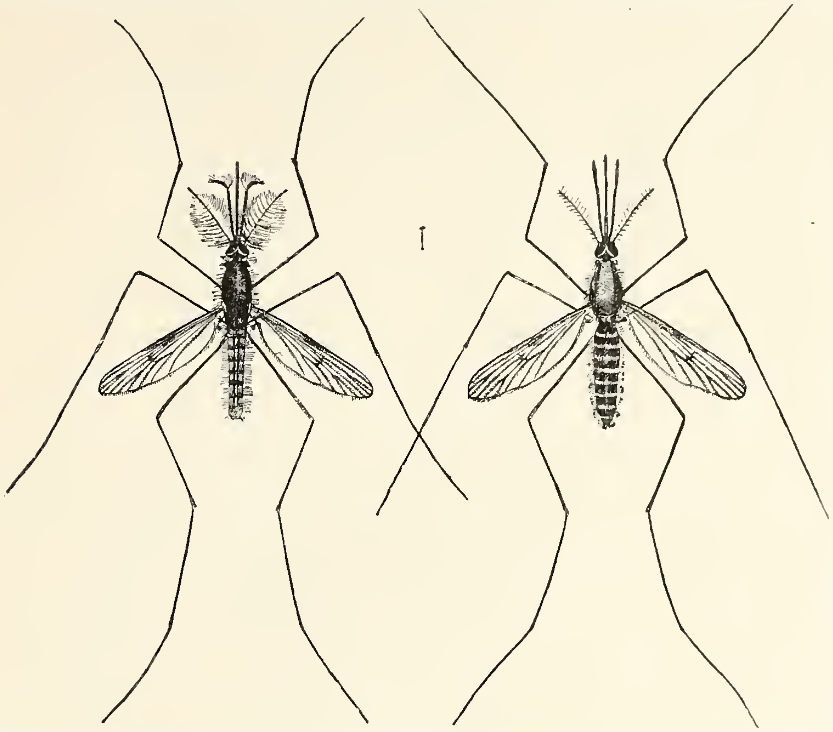

FIG. 3364.—*Anopheles maculipennis* Meig. Male at left, female at right. (After Howard, Bull. United States Dep. Ag.)

The etiological importance of this genus has been thoroughly demonstrated in its transmission of malaria, and it has also been shown to be instrumental in transmitting filiariasis. As a genus it is widely distributed, with the exception of the higher latitudes. Nuttall has shown that in England this distribution compares exactly with the old limits of ague, but the genus also occurs in districts where no ague is known to have existed. It does not follow that because *Anopheles* are found, malaria is present; but wherever the latter occurs, the presence of *Anopheles* in considerable numbers has been demonstrated. *Anopheles* is moreover accustomed to fly and to bite only after sunset, so that by keeping within well-screened houses after that hour malaria is avoided even in the worst infected localities. The bite of this genus is believed to be less irritating than that of other mosquitoes and from its habits of lurking near the ground it is less likely to be discovered. Its hum is said to be less distinct than that of *Culex* and of a lower pitch. The adults hibernate in woods, and the larvæ may be found both in fresh and in salt water, even after frost has occurred.

Anopheles punctipennis Say. Wings with the costa black, interrupted by a single large ferruginous spot a little outside the transverse veins, with also a smaller apical spot and some yellow spots near the tips of the long veins. Legs and tarsi nearly uniformly black. Thorax and abdomen deep brown, nude except for some yellowish-brown hairs; wings much longer than abdomen; head black with a scanty whitish frontal tuft, palpi and proboscis dark yellowish-brown unbanded, but rather lighter at the tips, length 5 to 7 mm.

This species is very widely distributed over our continent and is said to be called the "winter mosquito," having been taken when the temperature was only 6° F.

Anopheles maculipennis Meigen (1818) (Fig. 3364). Wings with four tufted spots on the wing field, the costa being uniformly dark except at the apex, where its color fades to form a fairly distinct spot; tarsi unbanded but with an apical yellow spot at the first joints. Thorax with four broad ferruginous stripes formed of golden hairs with the darker ground color left bare between and a tuft of large golden scales on the anterior border. Abdominal segments brown with yellowish basal markings. Anterior femora not thickened at the base. In the female the head with two patches of creamy scales divided by a central line, otherwise with black scales; a small tuft of white hairs in front and the borders of the eyes white. Male with antennæ banded, proboscis black, palpi dark brown. Length of male 4 to 7.5 mm., of the female 8 to 10 mm.

To illustrate the great variation of this species in size, Giles has drawn the wing of an Italian specimen over the wing outline of a Canadian specimen from the British Museum in a figure which is here reproduced (Fig. 3365).

The sub-family of the Culicina is the largest among the mosquitoes, and its type genus *Culex* includes more than one hundred and fifty species. In addition to the characteristics mentioned in the synopsis above it may be noted that the anterior fork cell is at least as long as the hind one. Of the dozen genera only two are noted.

Stegomyia Theobald 1901. Palpi short, four-jointed in the female; long, five-jointed in the male. Head clothed completely with an armour of broad, flat scales; mesothorax covered with either narrow curved or spindle-shaped scales. Scutellum always with broad flat scales on the middle lobe and usually also on the lateral lobes; abdomen completely covered with flat scales, banded or unbanded, but always with white lateral spots. The female palpi are small, never more than one-third the length of the proboscis; those of the male are as long as, or longer than, the proboscis. Wings of similar venation to those of *Culex*, but the fork cells are short. With hardly an exception they are colored jet black contrasted with pure white in bands and stripes on the legs and thorax, which is often elaborately adorned; in all black predominates, and they have a characteristic smooth satin-like appearance.

As these mosquitoes are rarely found north of 40° North latitude, they are characteristically tropical and subtropical forms. They are said to be good sailors and as a result *S. fasciata* belts the world with its colonies, being the most widely distributed of all mosquitoes.

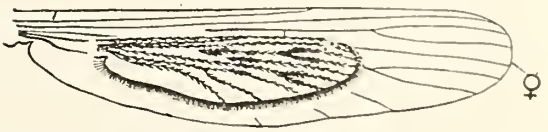

FIG. 3365.—Wing of *Anopheles maculipennis*. Outer outline to show size variation. (After Giles.)

The description of this cosmopolitan species is as follows:

Stegomyia fasciata (Fabr.). Wings (Fig. 3366) densely clothed with very long black scales of three lengths. Last hind tarsal joints and all but the apex of the next snowy; all the other joints of the hind, the upper three of the mid, and the upper two of the fore legs of the otherwise black tarsi basally white banded. Thorax from a velvety black with reddish reflections to a golden brown in some specimens, elaborately marked with rather broad silvery lines arranged in the form of a lyre (Fig. 3367). First abdominal segment creamy white, the others black with narrow basal bands and brilliant lateral tufts of snowy white. Proboscis unbanded, black. Head black with narrow white orbits and two faint patches of white on the occiput divided by delicate median and lateral black lines. Of moderate size, often very small, some even with wing length not exceeding 2 mm. In some places a pure rainy weather species.

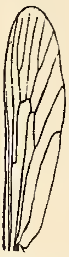

FIG. 3366.—*Stegomyia fasciata.* (After Giles.)

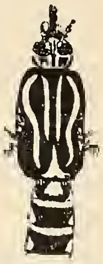

FIG. 3367.

The extreme variation in size and color markings has led to the frequent redescription of this form as a distinct species. Giles says that specimens hatched from the same tank vary so very widely as to render varietal limits decidedly uncertain. In the United States it is common throughout all the Southern States, having been found about as far north as Norfolk, Virginia, while its previous or occasional range as far as Philadelphia, New York, and Providence is clearly indicated in the epidemics of yellow fever at those places about the beginning of the last century. It is said to be troublesome in the early afternoon and again at night, in contradistinction to the majority of mosquitoes, which are twilight flyers. It certainly is a hardy species, and individuals infected with yellow fever have been kept alive seventy-one days, thus showing how contagion of yellow fever may cling to a building which has been vacated more than two months. According to Gorgas it breeds principally in yards in more thickly settled parts of the city, in all fresh-water collections, such as rain-water barrels.

Culex Linnæus. Palpi short, three- or four-jointed in the female, with the last joint usually large; long, three-jointed in the male with the last two joints swollen much as in *Anopheles*, or narrower with the last pointed. Antennæ fourteen-jointed; pilose in the female, plumose in the male, where the last two joints are long and thin. Head with narrow curved scales over the occiput and upright forked scales thick on the back of the head, with flat scales on the sides. Thorax with narrow, curved, hair-like or spindle-shaped scales. Scutellum with narrow curved or spindle-shaped scales only. Abdomen with flat scales. Wings (Fig. 3368) with small median scales on the veins and more or less thin linear lateral ones on some or all of the veins. In the wings the first submarginal cell is longer and narrower than the second posterior cell, and the posterior cross vein is always nearer the base of the wing than the mid-cross vein.

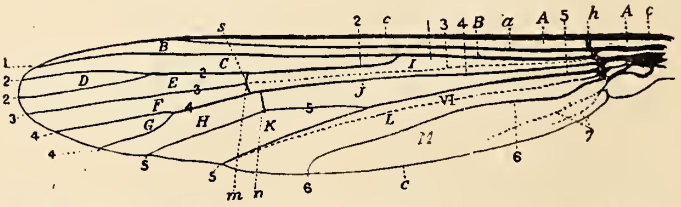

FIG. 3368.—Wing of *Culex concolor* (male) to illustrate Terminology. *c*, Costa; *a*, auxiliary vein; 1-6, first to sixth longitudinal veins and branches; 7, seventh or false (unscaled) longitudinal vein; *VI*, unscaled vein between fifth and sixth longitudinal veins; *h*, humeral transverse vein; *s*, supernumerary transverse vein; *m*, middle transverse vein; *p*, posterior transverse vein; *A*, costal cells; *B*, subcostal cells; *C*, marginal cell; *D*, anterior fork cell or first submarginal cell; *E*, second submarginal cell; *F*, first posterior cell; *G*, hinder fork or second posterior cell; *H*, third posterior cell; *I*, first basal cell; *J*, second basal cell; *K*, anal cell; *L*, axillary cell; *M*, spurius cell.

The extreme number of species included within this genus makes it difficult to find one's way even with the aid of a monograph. Here only a few of the most characteristic forms may be briefly mentioned. So far as is known *Culex* is responsible for the transmission to man of filarial disease only, although avian malaria is certainly transmitted by members of this genus. Experiments have shown that it is not concerned in the transmission of human malaria. The salt-water or ring-legged mosquito of the Atlantic coast, *Culex solicitans*, is a small gray mosquito with the legs banded in black and white. It breeds abundantly in the brackish swamps of the eastern coast from Florida to Maine. The larvæ may be found where the water carries one-fourth more salt than the sea, but it will not breed in fresh water. According to Smith it swarms twenty miles inland and is found occasionally as far as forty miles from its breeding place.

Culex pungens (Fig. 3369) is one of the most abundant and widely distributed species in the United States. It breeds in fresh water exclusively, and its larvæ are common in water barrels, cisterns, hollows in trees, and stumps, in city gutters as well as in transient pools, and in fresh-water swamps. In Havana, Gorgas found it breeding abundantly in cesspools and drains. Its life cycle occupies in summer a minimum of ten days, but its larvæ may live over winter, and adults have been reared from such larvæ found frozen in the ice. Further details regarding the genus and some other species of *Culex* may be found under *Insects*.

Structure and Habits.—Mention should be made of such structural features and such habits as are of special importance in the transmission of disease. The highly modified mouth parts of the mosquito are arranged for piercing and sucking. They consist of the upper lip or labrum (*a*, Fig. 3370) in the form of a long narrow spine, grooved ventrally and terminating in a sharp point, the still more slender lancet-like mandibles (*b*) and maxillæ (*w*) which lie one of each on either side of the hypopharynx (*k*), the latter having the form of a delicate blade through the central thickening of which runs a minute canal, and finally the lower lip or labium (*c*) which is merely a sheath for the other parts. Giles gives a most vivid description of these structures as follows: "Imagine a surgeon's 'director,' with a piece of thin drainage tube carried against its groove, and with four slender bistouries grouped round it, and you will have a fair working model of the malaria-inoculating apparatus of the mosquito." The upper lip bears at its base a bulb in which are muscle fibres serving as extensors and retractors. Its groove forms somewhat more than a semicircle, and is converted into a complete canal by the flattened hypopharynx lying just below; it is through this canal that blood flows into the mouth cavity. The delicate tube noted above, as piercing the hypopharynx, is the continuation of the salivary duct and through it the salivary secretion, with the "sickle spores" or sporozoites of the malarial parasites, is injected into the vertebrate host, while at the same time the blood of this host is flowing back through the labrum into the digestive cavity of the mosquito. In biting, the mandibles and maxillæ appear to cut a passage through the skin by the thrust of the head and the labrum is forced into the opening thus made, while the flexible labium holds together and directs the other parts, its stem being looped down out of the way as the latter proceeds deeper and deeper into the skin.

The course taken by the spores of the malarial parasite in reaching the new host can be reasonably set down about as outlined above; with the embryonic filariæ, however, the case is different and much less satisfactorily explained. These worms are known to bore their way out from the stomach of the mosquito into the muscles and thence through the connective tissue and lymph spaces through which they penetrate, even into the labium which possesses a considerable amount of suitable tissue. Here, in the opinion of Grassi, they produce swelling, and when the organ is sharply bent in biting the delicate covering is ruptured and the worms are set free, to find their way along the mouth parts and into the tissues of the new host. Bancroft maintains that the embryos of *Filaria immitis* always escape at the extreme tip of the labium as if a natural orifice existed there. On the other hand, the investigations of Kellogg in Samoa seem to show that the embryos of *Filaria Bancrofti* (= *F. sanguinis hominis*) are liberated from mosquitoes which die and fall into pools of water, and are taken up by the natives in drinking from these pools.

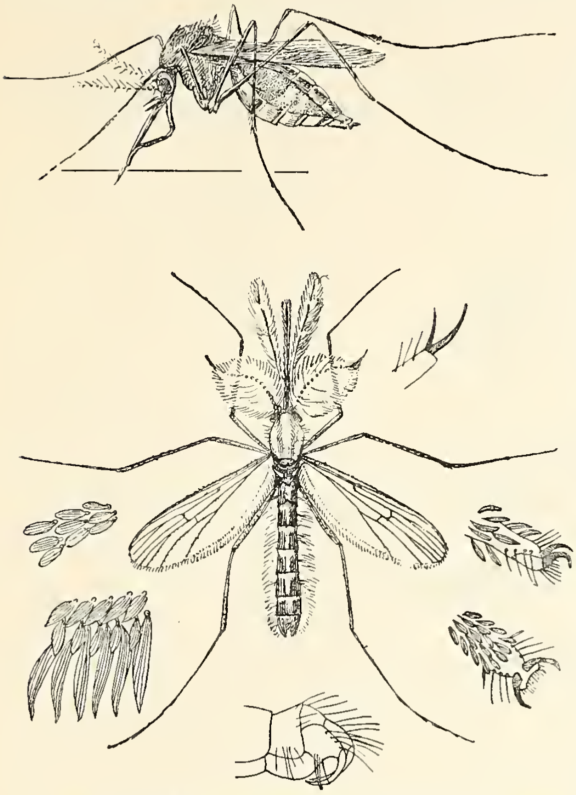

FIG. 3369.—*Culex pungens.* Female above, male below. Enlarged. (After Howard, Bull. United States Dep. Ag.)

The organism which produces yellow fever has not yet been discovered, and all statements regarding the precise mode of introduction into man by the mosquito are purely conjecture. The interval of twelve days or more which, according to the investigations of the Yellow Fever Commission, must intervene after contamination before the mosquito can carry the infection, shows clearly that the organism of the disease is not merely adherent to the mouth parts of the insect but enters its body and undergoes some part of its life history within the tissues, at the termination of which only is it in condition for transference to a new human host. In many ways it recalls the case of malarial parasites and a similar method of transference appears probable.

In other cases in which the mosquito acts as a supposed transmitter of diseased germs, the occurrence is more probably only a passive carrying, from one human host to another, of the germs which chance to adhere to the mouth parts. The case cited by Giles and mentioned more in detail below seems to fall into this class.

Though some species are active and annoying during the day, adult mosquitoes are generally nocturnal or twilight flyers, shunning the direct rays of the sun, which they cannot endure even for a short period. They hibernate in warm, dark places, and may be found in barns, cellars, and other out-of-the-way spots during the winter. During cool days in summer they do not feed, and their abundance and virulence are clearly related to rainfall and temperature. The natural food of all species is probably plant juices, and the male with rare exceptions does not go beyond this. For experimental purposes banana or dates constitute the most acceptable food articles. Even to the female, however, a meal of blood does not seem to be essential to reproduction in spite of the efforts made to obtain it. It was formerly believed that a female mosquito, after having had a single meal of blood, laid her eggs and then died. Several investigators have recently found that she may survive and bite again either before or after oviposition. It is this occurrence which inoculates man with malaria or yellow fever germs or filariæ.

When resting all mosquitoes support themselves on four legs, the last two being held waving in the air; but the posture of the body is sufficiently different to distinguish most forms of the two common genera. *Culex* stands with a noticeable hump, the head and mouth parts forming a decided angle with the thorax and abdomen, which moreover droops, while in *Anopheles* these regions form a single straight line which is oblique or even vertical to the surface on which the mosquito is resting. So far as known, this characteristic attitude has but a single exception (*Anopheles culicifacies* Giles), a species foreign to this continent.

Life History.—The female mosquitoes always deposit their eggs in water, and while the precise environment selected by each species is usually characteristic, the general statements made regarding different genera are often misleading. On the other hand, eggs and larvæ can be found and distinguished with ease. The eggs of *Culex* are deposited in an elongated boat-shaped mass (1, Fig. 3371) about the size and color of a caraway seed. These masses float on the surface until the embryos are hatched. *Anopheles*' eggs are deposited singly or in irregular detached groups, and each is provided with a floating organ (7, 8, 9, Fig. 3371) of air chambers to keep it at the surface. The eggs of *Stegomyia* (6, Fig. 3371) are also deposited singly and provided with a floating organ.

According to Carroll, Agramonte, and Lazear, they may be held dry for a month and yet develop when brought into water again.

The larvæ of all mosquitoes, familiarly known as "wrigglers," float at the surface for respiratory purposes, and if they leave this position it is only for a short time. Those of *Culex* possess a very large head, a long respiratory siphon, and hang head downward at a considerable angle with the surface (Fig. 3372). *Stegomyia* larvæ assume nearly the same position, though somewhat more nearly transverse since the respiratory tube is shorter.

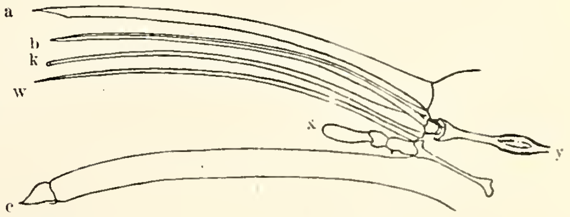

FIG. 3370.—Mouth Parts of Female Mosquito, diagrammatic. *a*, Labrum; *b*, mandible; *c*, labium; *k*, hypopharynx; *w*, maxilla; *x*, maxillary palp; *y*, basal joint of maxilla. (Paired organs represented by left member only.) (After Giles.)

The position assumed by *Anopheles* larvæ, however, is strikingly horizontal (Fig. 3373) and close to the surface. These larvæ have a small head, no siphon, and the respiratory orifices are almost level with the back. The head, which is held barely below the surface, has been turned on the neck through a half-circle so that its lower aspect looks upward as it feeds on the floating débris. The pupæ (Fig. 3374, A and B) are also different for the different genera. In all, however, they float at the surface, taking no food but obtaining air through a curious auriculate respiratory siphon, until ready for the emergence of the perfect insect, which occurs through the back of the pupal thorax; the pupal skin floats at the surface as a rest for the adult before the latter starts on its initial flight. The process of breeding is retarded by colder weather, and the larvæ may even be frozen in masses of ice, and yet after thawing out regain their activity. Many, doubtless, regularly pass the winter in this way in higher latitudes.

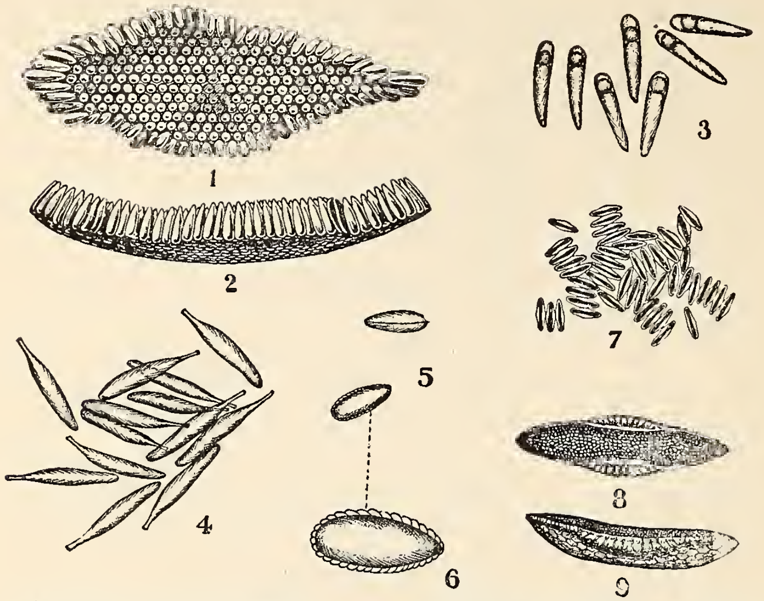

FIG. 3371.—Mosquito Eggs. 1, Egg mass of *Culex* seen from above; 2, same from the side (after Sambon); 3, separate *Culex* eggs; 4, eggs of *Panoplites* (after Daniels); 5, 6, eggs of *Stegomyia* (after Theobold); 7, group of *Anopheles* eggs floating; 8, 9, isolated eggs of *Anopheles maculipennis* to show floating organ. × 30. (After Nuttall.)

Diseases Transmitted by Mosquitoes.—There no longer exists a reasonable doubt that malarial disease is transmitted by the agency of mosquitoes. The painstaking elucidation of the life cycle of the hæmatozoa of malaria has demonstrated the existence of a sexual phase in the life history which takes place in the body of the mosquito and alternates with asexual generation found in human blood. (For further detail on the life history of this organism and its relation to the disease see article on *Plasmodium malariæ*). When Manson had a number of *Anopheles*, which had bitten a patient suffering from tertian ague in Italy, brought to England and there permitted them to bite two healthy students, who at a suitable time thereafter came down with malarial fever and showed the characteristic parasites of tertian ague in the blood, all objection to the possibility of this method of transmission of the disease was eliminated. Thus far no one has been able to find any other method of transference, save by operative interference, and to judge from the life history of other parasites which manifest alternation of generations in different hosts no other method is at all probable, as Giles has so forcibly and logically demonstrated. It would, however, be hazardous to maintain that the asexual generation, even of the so-called human malarial parasites, may not be found also in other vertebrates. The immediate and abundant appearance of malaria among travellers in regions which have been depopulated or in which man is at best very rare, points indeed to the existence of another host for the asexual generation. On the other hand the sexual generation is known to inhabit only mosquitoes of the genus *Anopheles*, and experiments to infect various species of *Culex* and of other genera have thus far proved futile. All data thus far obtained show not only that, given *Anopheles*, the possibility of malaria exists, dependent to some extent no doubt upon other factors, but also that "no *Anopheles*, no malaria" is equally certain.

The relation of the mosquito to elephantiasis (*q. v.*) and filariasis (see *Nematoda*) has been equally definitely established. Here the mosquito draws the embryo worms, still surrounded by a delicate embryonic membrane, with the blood into its stomach. The embryos bore their way thence into the muscles and after a brief stay wander out into the labium. As in malaria and yellow fever, there is here also a stage of incubation, but unlike the former it is not a period of reproduction for the parasites but merely for the growth of the larvæ which are ready to be transferred to the human host when the mosquito has digested its first meal and is ready for the second. In this case certain species both of *Culex* and of *Anopheles* have been shown to afford proper environment for the development of the young worms.

The recent brilliant discoveries of the Yellow Fever Commission have demonstrated that the mosquito serves as the intermediate host for the parasite of yellow fever, and that this parasite is transmitted after an interval of approximately twelve days to non-immune individuals by a mosquito that has fed on the blood of a yellow-fever patient. It is the more striking that this mode of propagation has been definitely determined since the specific cause of the disease is as yet undiscovered. The mosquito responsible for the transmission of yellow fever is *Stegomyia fasciata*, although in all probability the culpability is shared by other species of the genus, if not by other genera.

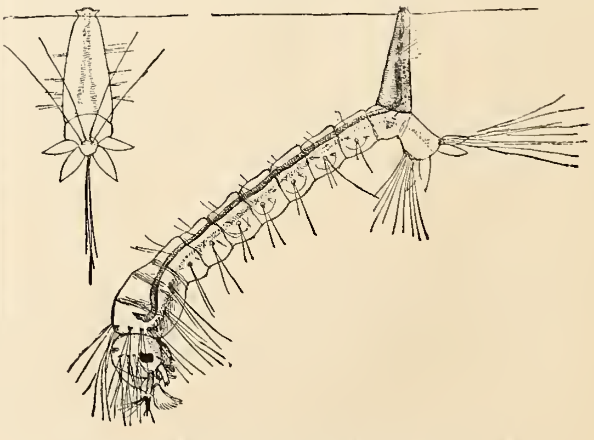

FIG. 3372.—*Culex pungens.* Larva in breathing position at surface of water. (After Howard, Bull. United States Dep. Ag.)

Recently Blanchard has summarized forcibly arguments to show that leprosy also is transmitted by mosquitoes. An ailment exclusively human, caused by a bacillus which grows only so far as known in human tissue and which cannot be transmitted by mere contact, the intervention of a biting insect appears indispensable that the bacilli may be brought into a favorable environment.

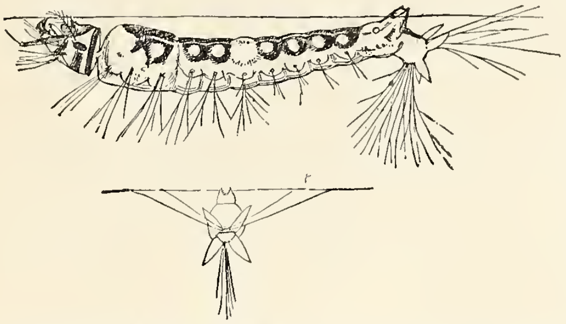

Fig. 3373.—*Anopheles maculipennis* Meig. Larva showing breathing position at surface of water. (After Howard, Bull. United States Dep. Ag.)

That the rôle is assumed by the mosquito rests only on conjectural and yet very probable grounds.

It has also been conjectured that tubercle bacilli are transmitted by mosquitoes, without positive evidence having been found for the view. While such unconfirmed suppositions must be regarded with suspicion, it is certain that in some instances bacteria are transmitted by mosquitoes. This is clearly shown by the observations of Giles on natives of India who had "applied for treatment on account of their faces being so swollen that they could scarcely open their eyes, and the fact that such cases are specially apt to occur among patients lying in a surgical ward makes it probable that the unusual effect of the bites in such cases is due to the mosquitoes having indulged in a previous feed from some wound secretion."

In this connection mention should be made of the annoyance caused by mosquitoes, of the irritation due to their bites, very noticeable in some persons, and of the limitation which these disturbances put upon the enjoyment and full utilization of the opportunities for invigorating outdoor existence which the warmer part of the year affords and the health of every individual demands. While trivial perhaps in the individual instance, it amounts in sum total to so much that for its remedy alone the severest measures against these pests should be advocated. When the loss of life and economic disturbance produced by yellow fever, and the still more serious but less striking since prolonged effects of malaria are taken into consideration, abundant reason exists for the immediate action of civilized communities to abate the mosquito nuisance. It must also be borne in mind that the casual introduction of a case of malaria, yellow fever, or elephantiasis into an otherwise healthy region gives conditions which may lead to the spread of the malady, if the place happens to be infested with the proper mosquito.

Dispersal of Mosquitoes.—The agency of mosquitoes in transmitting disease necessitates a consideration of the means which bring about the dispersal of the insects. In general, mosquitoes are home bred; and while this is true of *Culex* it is even more characteristic of *Anopheles.* Ross was able to find no case in which the distance from the infected house to the breeding-ground of this species was greater than one hundred and fifty yards. *Stegomyia* is said by Gorgas to be a very domestic mosquito, seldom leaving the immediate neighborhood of the place of its birth. The cause of a mosquito plague is then strictly local, although Smith thinks that swarms of the salt-water mosquito, *Culex solicitans*, may be carried twenty or even forty miles by a favorable wind. In most cases, however, it is clear that natural agents do not disperse them so widely. Howard has given numerous cases of their introduction into new regions by railway trains, and Grassi furnishes equally good evidence of their transportation by stage coaches.

Some observations have been made on the rôle of vessels in carrying mosquitoes from port to port. The insects probably are transported long distances in sheltered parts of the vessels and will breed in water barrels, and perhaps even in bilge water, during a voyage, thus furnishing a constant supply of adults. The emergence of mosquitoes from concealment on board ship would serve to explain the sudden outbreak of yellow fever at considerable intervals after leaving port. Ships coming into harbor have recorded swarms of mosquitoes carried out ten or even twenty miles by gentle off-shore winds. In this way vessels anchored at a considerable distance from infected ports, or even passing them without having had any direct communication, are subject to contamination with diseases transmitted by mosquitoes.

Prophylaxis.—In view of the part played by the mosquito in the transmission of disease, it is fitting to inquire in the next place what means are available for the correction of the evil. A number of methods have been suggested which differ somewhat in applicability and efficacy, but all of which are valuable in certain cases. First may be mentioned the protection of individuals against the bite of the mosquito. This is accomplished by means of protecting the house with screens of mosquito netting or fine wire gauze in both doors and windows, or by screening beds with curtains of fine gauze, which completely shield the sleeper from the attack of the insect. In the case of persons engaged in outdoor employment it is necessary also to adopt some type of protection for the exposed parts of the body, such as wearing gloves on the hands and hoods or veils of netting over the face and neck.

The results of this practice are, that those in good health are not infected with the parasites carried by the mosquito, and on the other hand that sufferers from the disease do not give infection to the mosquitoes of the neighborhood. In the latter case it is imperative that such should not become sources of infection for the entire neighborhood, and the spread of the infection may be prevented by timely and perfect protection of the invalid from the attacks of mosquitoes. It is reasonable to require that all cases of malaria, as well as yellow fever and other infectious diseases, should be reported to the public health officer and that the isolation of the patient from mosquitoes be rigorously carried out, for otherwise the introduction of a single case may be the source of infection for an entire neighborhood. This has repeatedly been seen within recent times, as when, by the return of soldiers from the Spanish war, a previously unin-

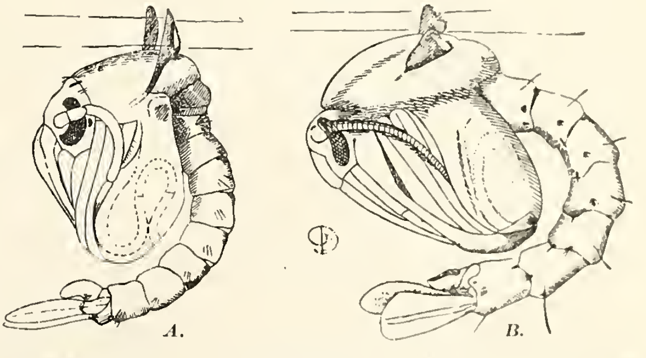

Fig. 3374.—Pupæ of *A*, *Culex pungens*. *B*, *Anopheles maculipennis*. (After Howard.)

fected neighborhood has been infected with a veritable epidemic of malaria.

This method has been successfully employed among the railroad operatives in Italy by Celli and Grassi with results so pronounced that the latter has proclaimed the possibility of freeing Italy entirely from malaria within a short time and making the most dreaded regions into health resorts. Under protection from mosquitoes, house epidemics of malaria ceased and convalescence was as easy at home as with change of air. Outside of the protected houses hardly a person escaped the disease; within them hardly any one was infected. Such mechanical prophylaxis is of the greatest advantage, particularly to those whose employment compels them to remain in a badly infected region. But it is after all a temporary measure and unattainable for a large part of the population of the world and under the conditions of tropical climates.

As protection against the bite of the mosquito, use has also been made of their repugnance to strong odors with meagre success. The essential oils of lavender, citronella, and eucalyptus are effective, when rubbed on the skin, in discouraging the attacks of mosquitoes; but the greatest success has been attained with the formula: castor oil, ℥ i.; alcohol, ℥ i.; oil of lavender, ʒ i. As a remedy for the irritating effects of the bites so noticeable on some persons, glycerin, alcohol, and indigo have been recommended, but in my experience tincture of iodine is best where the location of the bite does not inhibit its use, and is successful in the worst cases.

It has also been suggested by Koch that the generous and universal use of quinine would destroy the malarial organisms and thus do away with the disease. It may be doubted whether even under governmental support such a method could be sufficiently generally applied, in spite of the prejudices of a considerable part of the population, in temperate regions at least, even to approximate the end sought. The use of quinine will always be in favor among the educated part of the population of malarial regions and with travellers who are called upon to penetrate fever-ridden territory. Its sale at cost under government authority is a wise measure for the sanitary improvement of general health in the tropical colonies. In temperate regions many cases of malaria are not recognized as such; and it should be noted, moreover, that while affecting a most important element of the mosquito problem, the proposed method does not offer any solution for the other factors concerned.

The destruction of mosquitoes in the adult condition may be brought about by various means. In order to control yellow fever effectually this is essential as well as the protection of the sick against the bites of the mosquitoes. Most convenient of all is the burning of pyrethrum powder, although chlorine gas, formol vapor, chloral, and sulphur may be used with success also. The natural enemies of the adult mosquito are not rare, but it seems impracticable to hope to reduce noticeably the numbers of the insect by the multiplication of its enemies.

A more successful point of attack is offered by the immature larvæ and pupæ together with their breeding places. The large majority of the latter are not essential and many of them are indeed accidental collections of water, so that the most radical as well as the most effectual treatment of the subject is the abolition of such breeding places. To this end Ross has advocated the formation of mosquito brigades and the thorough examination and treatment of a region. This consists in the destruction of all unnecessary breeding spots and the regular treatment of necessary bodies of water so that they may not endanger general health by producing swarms of the insect. It is perfectly practicable in this manner to remove the sources of the infection and to reduce to the minimum limit the mosquitoes in any locality, since, as has already been mentioned, these insects are home bred and are rarely found at any considerable distance from their breeding places.

For a work of this character there are necessary: first, accurate knowledge regarding the location, number, and extent of the breeding places; second, capable treatment of the smaller localities that they may remain free of water even when it rains; and third, a scientific plan for handling the larger water areas that they may not serve for the production of mosquitoes. The smaller pools can usually be filled or drained by deepening the outlet without any considerable expense. The ease and effectiveness of such drainage work are entirely unappreciated, and the removal of a few small pools by draining or filling will often completely abate the mosquito nuisance in a given locality. Larger bodies of water require the cleaning away of marsh plants at the margin and the introduction of fish, such as the stickleback, sunfish, and goldfish, which are natural enemies of the larvæ. A most admirable example of the proper method for the treatment of the problem is given in the report on plans for the extermination of mosquitoes on the north shore of Long Island.

In many cases the most useful and successful method for the destruction of larval mosquitoes is the use of kerosene which has been advocated by Howard and has been successfully employed in many cases. The kerosene spreads over the surface and forms a film which smothers the larvæ and pupæ and catches the females as they come to deposit eggs. For the petrolization of a pool what is known as low-grade fuel oil which spreads rapidly and evaporates slowly is recommended and is best applied by pouring it on the surface of the water; spreading the oil through a spraying nozzle is less economical. Water treated with kerosene once a fortnight should be perfectly safe and the oil will not harm other animals than the aquatic insect larvæ.

The destruction of the mosquitoes and their breeding places has attracted much attention recently. The responsibility of the individual for the maintenance of his own property free from nuisance is thoroughly recognized and the breeding of mosquitoes will soon be included as a nuisance everywhere as it has been in several places, notably Havana, of which Ross speaks with admiration, commending "the straight-thinking Americans who quickly fine a person who breeds mosquitoes." That campaigns against mosquitoes are not only reasonable but eminently successful has been abundantly proved by work in many localities in the United States under the direction of Howard and others, by the work of Young in Hong-Kong, of the United States army in Cuba, and most striking of all by the campaign of Gorgas in Havana. Within ninety days after the adoption of regulations providing for the effectual isolation of the sick and for the destruction of all mosquitoes present in the infected and the neighboring houses Havana was freed from yellow fever; and in spite of repeated introduction of the disease from without, the death rate from yellow fever, which had averaged four hundred and sixty-two annually for ten years previous, was reduced to a total of five in 1901, and for malaria the reduction was from about three hundred and fifty in 1900 to only twenty-six for the first four months of 1902.

Results.—Finally it is proper to call to mind the effects which will be produced by the extermination of the mosquito. These evidently depend upon the character of the diseases. Yellow fever consists of a single illness followed by greater or less immunity from subsequent attacks; consequently the extermination of the mosquito will bring about the immediate disappearance of the disease. This has been the case in Havana. Elephantiasis and malaria, however, are protracted diseases. The parasites remain alive for years after the time of introduction by a mosquito. Elephantiasis is a permanent disease, and in malaria relapses occur long after the removal of the effecting agent; hence after the disappearance of all mosquitoes in a locality those persons who were previously infected will continue to suffer from these two diseases, so that not much change may be found within a period of several years. And yet a single year's work in mosquito extermination in Havana reduced the mortality from malaria in that city ninety-three per cent. within eighteen months.

In consideration of the enormous losses which Celli sums up for a single country in the positive assertion that "malaria costs Italy annually thousands of lives and incalculable treasure," and in view of the even greater losses of other countries, it is not too much to hope that extended action may soon be taken through governmental agency for the correction of the evil by the eradication of the mosquito. *Henry B. Ward.*

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END OF VOLUME V.

Nematoda

puerperal eclampsia, tuberculosis, toxæmia of burns, etc. The foci are found chiefly in the liver, spleen, lymph glands, and kidneys. The form of the necrosis is usually simple, but fibrin is often present in the necrotic material. The later stages present the appearance of caseation. Focal necroses may not be visible to the naked eye, or they may resemble miliary tubercles or abscesses, for which they may be mistaken. At other times they may appear as small pale yellow or grayish spots barely distinguishable from the surrounding normal tissue. Microscopically, small islands of simple coagulation or caseation necrosis are found. When the necrosis has been recent, diffuse or fragmented chromatin may be present and the areas may stain deep blue. About the necrotic areas there is often a leucocyte infiltration. Many of the leucocytes become involved in the necrotic process; their chromatin becomes diffuse, giving rise to a deeply staining periphery. In the liver focal necroses are often limited to the central zone of the lobule about the central vein; hence the designation *central necrosis*. The same term is also applied to central necroses of bone. Focal necroses are due to the direct action of bacilli or to poisons acting directly upon the cells or to local asphyxia. The changes in the small capillaries of the affected tissue play a very important part. Fibrin may be first formed in the capillaries and lymph vessels, and thus shutting off the supply of nutrition cause cell death. In other cases changes in the capillary walls may be first produced by the injurious agent; capillary thrombosis follows, and to this the cellular necrosis may be secondary. Transudation of serum through the injured capillary walls may also lead to necrosis of the surrounding cells. The sequelæ of focal necrosis are the same as those of necrosis in general.

Fat Necrosis.—The necrosis of the fat-containing cells of adipose tissue forms a condition so striking in its clinical and pathological aspects as to warrant special mention. The condition occurs most frequently in the abdominal fat in connection with pancreatitis. The necrotic areas appear in the fat as grayish or yellowish, or in some cases black, opaque areas, soft or gritty, slightly elevated and usually circular in outline. The appearance sometimes is such as to suggest that the fat had been seared by a hot iron. Microscopically, the fat cells are enlarged, the nuclei absent, the contents granular or presenting the appearance of fine needles radiating from the centre of the cell. Osmic acid has no effect upon the altered fat cells. With ordinary stains the necrotic fat cells react in a variety of ways. The granular detritus in the fat cells consists of a combination of lime salts and fatty acids. If the process is old, the amount of lime salts may be great. It has been definitely shown that fat necrosis is due to the fat-splitting ferment of the pancreas, which under certain inflammatory conditions of that organ gains access to the tissues through the blood or lymph. Experimentally, fat necrosis may be produced by injection of pancreatic extract, by ligature of the pancreatic vessels, by introduction of pieces of pancreas into adipose tissue or into the peritoneal cavity, and by the direct action of steapsin in fat tissue. Not only may the abdominal fat be affected in cases of pancreatitis associated with fat necrosis, but also the fat of the pericardium, liver cells, retroperitoneal region, and bone marrow. In the majority of cases the condition is fatal, but recovery has been noted, the dead fat cells becoming calcified.

Hæmolysis, the destruction of the red blood cells, and *leucolysis*, the disintegration of leucocytes, are discussed by some writers under the head of necrosis. The exact nature of these processes is not at present definitely determined. Bacterial products, various poisons, the blood sera of animals of different species, or of the same species under certain conditions, are the chief factors in the production of these conditions. Normal hæmolysis occurs in the spleen, lymph glands, hæmolymph glands, and bone marrow. In pernicious anæmia, sepsis, and many of the acute infectious and intoxications hæmolysis occurs in these organs to a greatly increased extent. Pathological destruction of the red cells in the circulating blood occurs also in a variety of infections and intoxications. The term *hæmocytolysis* is more properly applied to this condition, but has been largely superseded by the word hæmolysis.

Sequelæ of Necrosis.—The course of the necrotic process depends upon the anatomical nature and location of the affected tissue, the course and manner of the injurious influence causing the necrosis, the condition and environment of the affected part, the amount of blood and lymph, the nature of preceding changes, the opportunity for the access of air and putrefactive agents to the part, etc. About the necrotic area there is always a more or less marked inflammatory reaction in the surrounding living tissue. As a result of such inflammation the necrotic area becomes isolated and sequestered. The process is called *sequestration*, and the area of necrotic tissue so shut off a *sequestrum*. The ultimate sequelæ will be: (1) *Regeneration* following the absorption or casting off of the dead tissue, new tissue resembling the normal being formed; (2) *cicatrization*; (3) *calcification*; (4) *cyst formation*, the dead tissue being liquefied and encapsulated; (5) *chronic abscess* or *ulcer*.

Aldred Scott Warthin.

NECROSIS OF BONE. See *Bone, Pathology of.*

NEMATODA.*—The class of the Nematoda or round worms constitutes a large, rather uniform, and clearly demarcated group, which by many recent authors has been regarded as of the rank even of a phylum, in which case the name Nemathelminthes has been applied. The group is characterized by a cylindrical body, often filiform even in its attenuation, and by the heavy cuticular investment which carries in some cases small bristles, hooks, or spines, but which is consistently without appendages and manifests at most surface striation, but never true segmentation. The body cavity is extensive, but unprovided with a peritoneal epithelium, and the sexual and excretory systems do not stand in any connection with it. Another striking feature is the entire absence of cilia in all stages of development.

An alimentary canal is present, at least in some stage of the life history of all forms. It is with rare exceptions a permanent structure in the members of the sub-class of true round worms, or Eunematoda; but in the sub-class of the hairsnakes or Gordiacea, the alimentary canal is greatly reduced in the adult, in that the mouth is closed and a delicate solid string of tissue is the only vestige of the anterior portion of the canal. The posterior region still retains its cavity and functions in connection with the reproductive organs of both sexes, which have with it a common outlet. In the Eunematoda, on the other hand, the male organs join the alimentary canal to form a common cloaca, but the female system is entirely unconnected with the alimentary system, and the vulva occupies a variable position in the midventral line. The sexes are separate, though in rare instances parthenogenesis or hermaphroditism modifies the usual balance.

By far the largest number of forms belongs to the Eunematoda, which will be considered first, while the Gordiacea and, as an appendix, the Acanthocephala will be discussed subsequently. Among the Eunematoda the better known forms are parasitic, though some are free living and an occasional species is capable of making use of both types of environment. The free living species are uniformly insignificant, but among parasitic forms one finds the microscopic blood parasites and the meter long guinea worm. In respect to location also there obtains great variety; and one finds these parasites in all regions of the alimentary, respiratory, circulatory, excretory, and muscular systems, and in connective tissue and serous cavities.

The greatly elongated cylindrical form tapers as a rule more or less toward both ends, though generally speak-ing the head is truncated and the tail acute. The chitinous cuticula invests the entire body, and is introverted a short distance at all orifices. It bears rarely unjointed spines and bristles and is marked often by delicate surface striations. In cross section (Fig. 3537) the body appears circular, and shows beneath the cuticula a thin hypoderma layer, which is prominently thickened at four points. Of these the lateral lines, fields, or areas, as they are called, are largest, and are visible in surface view as delicate longitudinal stripes (*c*, Fig. 3535). The dorsal and ventral median lines are much less prominent and are distinguishable ordinarily only in sectional views.

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* A general discussion of parasitism and its effects will be found under the heading *Parasites*.

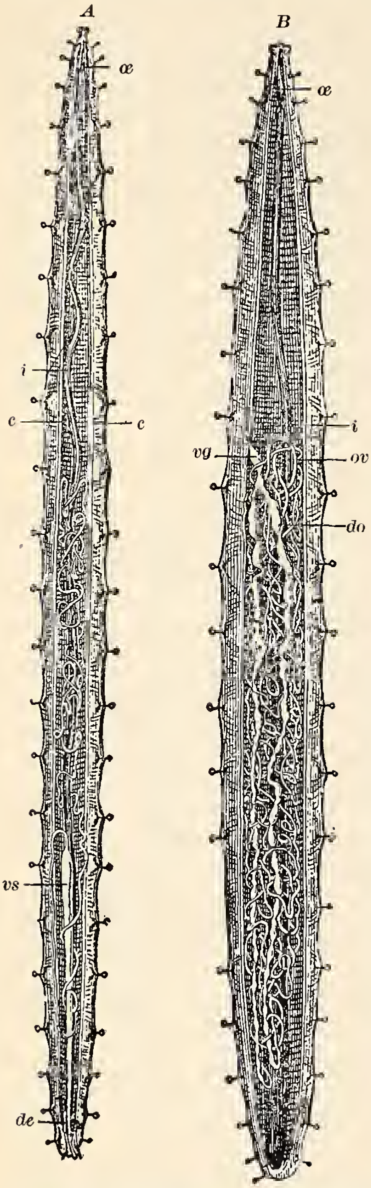

Fig. 3535.—Internal Anatomy of *Ascaris lumbricoides*, opened along dorsal line. *A*, Male; *B*, female; *c*, lateral line; *de*, ductus ejaculatorius; *do*, uterus; *i*, intestine; *œ*, œsophagus; *ov*, coiled ovary; *vg*, vagina; *vs*, seminal vesicle. (After Delafond.)

Directly below the hypodermis is the muscular layer which is interrupted by the lines already noted, and hence appears as four muscular fields. The muscle cells (*m*, Fig. 3536) are of a peculiar type in that a protoplasmic body is distinct from the contractile fibrillar portion. The main trunks of the nervous system occupy the dorsal and ventral areas, while the lateral areas contain each a delicate canal, which has been interpreted as part of the otherwise unexplained excretory system; with the latter are associated, however, certain stellate cells of peculiar character, which project from the lateral fields into the body cavity and are known as phagocytic organs.

The alimentary canal (*i*, Fig. 3535) is a straight simple tube extending from the mouth, which is always terminal, to the anus, which varies in location from the posterior end to a position on the ventral surface, some little distance removed from it. Various features connected with the canal are of great systematic importance. About the mouth are found a number of lips and papillæ characteristic of the genus or family. The buccal or pharyngeal cavity, an enlargement at the outset, the muscular œsophagus with a triangular lumen (Fig. 3537) and a terminal enlargement which may be indistinctly marked, or may partake of the form of a distinct bulb, or even two such, with a valvular apparatus, the intestine proper followed by the rectum and cloaca in the male—these constitute the distinct parts of the alimentary system.

The sexual organs have the form of a long coiled tube, in the attenuated distal end of which the sexual cells are produced, while the proximal portions afford storage for the perfected germ cells before they are discharged from the body. In the female the system is regularly bifid, although one horn of the uterus may be undeveloped to a greater or less extent, while in the male only a single tube is present. The varied debouchment of the system in the two sexes has already been noted. About the vulva chitinous lips often of notable thickness are developed, and on the external surface near the male orifice numerous papillæ characteristic of the genus or species, and at times a sucker also are to be found; these function as accessory copulatory apparatus, while in the same category are included expanding folds of the body wall known as the bursa and awl-shaped chitinous structures called spicules. The bursa varies from a pair of simple folds lateral to the cloaca to a cup or bell surrounding it and the posterior end of the body. The spicules, either one or two in number, with an accessory guiding piece in some instances, are developed in a dorsal evagination from the cloacal wall and provided with special musculature for extrusion and retraction. Their form varies greatly in different species, and with the bursa and circumanal papillæ constitutes the means for determination of the species.

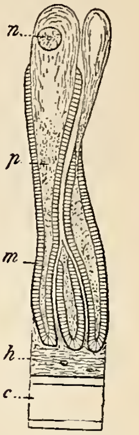

Fig. 3536.—Section of Body Wall. Highly magnified. *n*, Nucleus and *p*, protoplasmic body of muscle cell, *m*.

The Eunematoda are oviparous, but in some cases the eggs are retained long enough in the uterus to contain when laid a partly or fully developed embryo; and in a few species the embryo deserts the shell before it is extruded from the body. All stages in the development of this ovoviviparous habit may be observed.

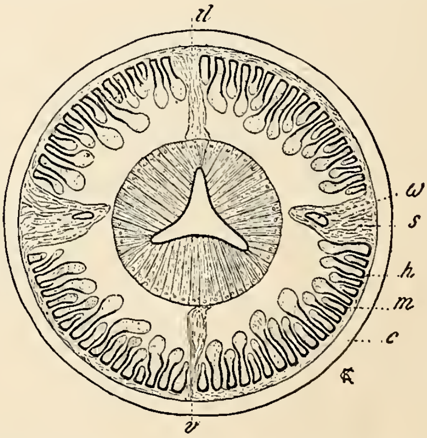

Fig. 3537.—Transsection of *Ascaris lumbricoides* at level of œsphagus. *c*, Cuticula; *h*, hypoderm; *i*, intestine; *m*, muscle layer; *d*, dorsal, *s*, lateral, *v*, ventral lines; *w*, excretory canal. (After Hertwig.)

Ordinarily the eggs which undergo development external to the body of the host are provided with a heavy shell to resist the action of an unfavorable environment. In case the eggs undergo development while still in the uterus, the shell is thin. Some species develop directly, *i.e.*, without a change of host, though a certain stage in the life history at least is passed in the outer world; in other cases the immature worm lives in another animal, known as the intermediate host, than that which harbors the adult, or rarely in a different part of the body of the one host. In a few species a parasitic generation alternates with a free living generation of such different form as to have been regarded as another species; and the alternating generations differ radically in method of reproduction. In one case at least (*Trichinella*) the entire life history is passed within the host and transportation to a new host depends upon the carnivorous habit. In other cases also (blood filariæ) the life history is passed within two hosts and no part takes place externally; but in most instances there is a free living stage and infection is brought about primarily through the drinking-water. Some prominent exceptions to this general statement are noted later.

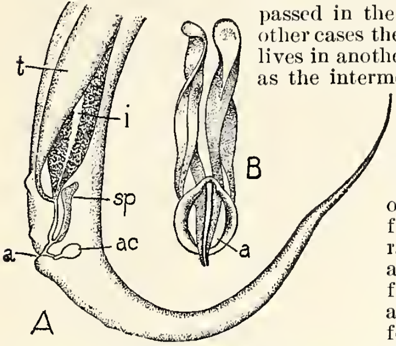

FIG. 3538.—*Anguillula aceti.* *A*, Tail of male; *ac*, accessory piece; *sp*, spicules; *B*, spicules partially protruded from anus. Magnified. (After Stiles.)

The family of the Anguillulidæ, which is difficult to characterize, contains mostly free nematodes of small size, transparent, filiform, and tapering to both ends. The œsophagus is inflated or has one or two bulbs at the posterior end. The female possesses double symmetrical uteri and short reflexed tubular ovaries, with vulva at or behind the centre of the body, with few, large ova, and with development rapid, often ovoviviparous. The male has two equal chitinous spicules, with or without one or more accessory pieces. The type genus is

Anguillula Ehrenberg 1826.—Buccal cavity very minute; œsophagus cylindrical with two bulbs, the posterior having a valve apparatus; vulva behind centre of body; male without bursa; accessory piece single, fan-shaped. The best-known species is the vinegar eel, which has recently been found as a parasite of man.

Anguillula aceti Müller (Fig. 3538).—Cuticula unstriated, body tapering slightly anteriad; tail greatly attenuated. Male 1.35 to 1.45 mm. long by 24–28 μ wide. Spicules 38 μ long, similar, twisted; accessory piece slightly caudad; no bursa; papillæ at least two preanal and one postanal. Female, 1 to 2.4 mm. long, by 40–72 μ in diameter, contains embryos 0.22 mm. long by 12 μ in diameter.

This worm, which is everywhere common in vinegar, has been recently studied by Stiles and Frankland in the rôle of a human parasite. The specimens were taken in great numbers from the urine of a female patient, and were present during a period of thirty-three days. The urine was always very acid and once had a marked odor of vinegar. In this sample the worms lived two months, and individuals then removed to vinegar became vigorous and bred rapidly.

Pathology.—The patient had chronic parenchymatous nephritis of a degenerative type, and the urine frequently contained albumin, but not while the parasites were present. No symptoms traceable to them were observed, and their presence in the bladder remained unexplained. The suspected use of vaginal douches acidulated with vinegar was denied by the patient, and no grounds existed for questioning the truth of the statement. Evidently this parasite might be present in the vagina if such a practice were followed. Billings and Miller have reported two other cases from the United States in which, however, the source of the parasite was not demonstrated beyond question.

Leptodera A. Schneider 1866.—Œsophagus with two bulbs, the posterior with or without valves. Male with or without bursa, often six to ten papillæ on the bursa or on the median line; two short spicules and a single accessory piece. Some species are hermaphroditic. A somewhat indistinct genus, difficult to separate from that last described, and perhaps identical with it.

Leptodera Niellyi R. Blanchard 1885.—(Syn.: *Anguillula leptodera* Nielly; *Rhabditis Niellyi* R. Bl. 1888.)

This species is known only in the larval form, in which it measures 333 μ in length and 13 μ in breadth. The alimentary canal was the only internal organ described; it displayed two enlargements in the pharynx, the second pharyngeal bulb having a dentate armature.

The worms were discovered by Nielly in 1882 in a young man, fourteen years of age, who was born near Brest, and had never been out of that region. A dermal eruption, much like craw-craw, of about five or six weeks' standing, affected chiefly the patient's limbs. In the fluid of each papule were found several worms, and the blood showed on microscopical examination at the outset of the malady many small nematoda, which, however, could not be found later; at no time were they found in fæces or urine.

The method of the introduction of the parasite was unknown; but it was remarked that the lad had been in the habit of drinking from brooks. It is easily surmised that the eggs of the worm were swallowed in drinking, and that the embryos, hatching out in the alimentary canal, bored their way into the circulation and thus reached the skin. Their presence both in the blood and in the papules is thus easily explained. They may have been, however, larvæ of some imported filaria, though dermatosis caused by larval nematoda has been observed in dog, fox and horse in Europe by many investigators.

In this connection it is important to note the similarity of this case to craw-craw, a contagious vesicular eruption of the skin, observed in Africa and in South America, in which various investigators have reported the presence of larval nematoda. Manson regards craw-craw as a dermatosis characteristic of the "sleeping sickness," endemic on the west coast of Africa. Moniez has suggested that the parasites to which this case is due may have been imported by some sailor from Africa, and associates with it the case of elephantiasis, also observed in Brittany.

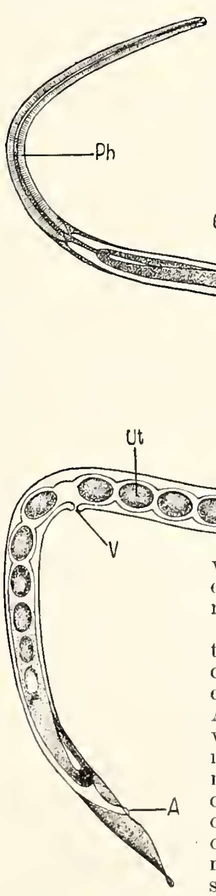

FIG. 3539.—*Strongyloides stercoralis* from Human Intestine. × 80. (After Braun.)

Leptodera pellio (A. Schneider 1866).—(Syn.: *Rhabditis pellio* A. Schneider 1866; *R. pellio* Bütschli 1873; *R. genitalis* Scheiber 1880.)

Male: Length, 0.8–1.5 mm.; bursa with seven to ten ribs on each side; spicules 27–33 μ in length, nearly alike. Female: Length, 0.9–1.3 mm., posterior extremity long and pointed, vulva a little in front of the middle; ovary not paired; eggs oval, 60 by 35 μ.

Scheiber found this species at Stuhlweissenburg, Hungary, in the urine of a native woman suffering from pyelonephritis, pneumonia, and acute intestinal catarrh. During the entire illness the worms were found in the vagina in all stages of development. Several other authors have found what is closely related, if not the same form, in the urine in cases of hæmaturia; but the parasitism is probably accidental, since Oerley has shown that *R. genitalis* Scheiber must be referred to *R. pellio*, a common free living form found in moist earth and putrefying substances, and also that worms of this species will multiply in the vagina of white rats. There is further to be noted both the habit of Hungarian peasants in employing moist earth for poultices and the record of Scheiber, that patient and clothing were earth-stained, rendering it altogether likely that such a poultice had been applied near the vulva, and that from it the free living worms had successfully colonized the vagina.

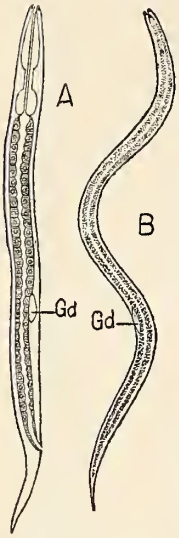

FIG. 3540.—*Strongyloides stercoralis.* *A*, Rhabditiform larva from fresh fæces. × 145: *B*, filariform larva from culture; *Gd*, genital cell. × 135. (After Braun.)

Leptodera terricola (Dujardin 1845.)—(Syn.: *Rhabditis terricola* Duj. 1845; *Pelodera teres* Schneider 1866; *P. setigera* Bastian 1879; *R. Cornwalli* Cobbold 1879.)

Mouth with six lips, anterior bulb of pharynx fusiform, posterior spherical. Male: Length, 1.3 mm.; tail attenuated, slightly longer than the bursa. Female: 2 mm. in length and over; posterior extremity sometimes regularly attenuated, sometimes sharply rounded and provided with a very fine tail; vulva about the middle of the body; ovoviviparous; eggs 60 by 40 μ.

This typical free living species should be listed as a pseudo-parasite of man by virtue of its occurrence in cadavers, and, in one case at least, its confusion with trichina. The facts in this celebrated case are as follows: The English schoolship *Cornwall* was visited in 1879 by an epidemic which affected many cadets and killed one. The symptoms of the disease were not incompatible with trichinosis, and microscopical examination of the exhumed cadaver, undertaken two months later, demonstrated in the muscles of the abdomen many nematoda, which, with the exception of the first one examined, were dead, but not one was encysted. The epidemic was pronounced therewith trichinosis, and attracted enough attention to be brought before Parliament. Cobbold and Bastian easily showed that the worms in question had nothing to do with *Trichinella*, and Oerley established their identity with *L. terricola*, which had undoubtedly penetrated the body after inhumation.

The family of the Angiostomidæ includes small rhabditis-like nematoda which manifest in development the alternation of two types of sexual generations of which the first is diœcious, free and very similar to Leptodera, while the second is parasitic, hermaphroditic, and of a different structure.

Strongyloides Grassi 1879.—Parasitic generation with simple mouth in which no armature is present; cylindrical pharynx very long. Free generation with small oral cavity; pharynx with two bulbs, the anterior fusiform, the posterior spherical and armed; male with two small spicules similar.

Strongyloides stercoralis Stiles and Hassall 1902.—(Syn.: *Anguillula intestinalis* and *A. stercoralis* Bavay 1877; *Leptodera intestinalis* and *L. stercoralis* Cobbold 1879; *Pseudorhabditis stercoralis* Perroncito 1881; *Rhabdonema strongyloides* Leuckart 1883; *Strongyloides intestinalis* Grassi 1883; *R. intestinale* Blanchard 1885.)

Free generation (Bavay's *A. stercoralis*) both sexes occur; body slender, tapering toward the ends; mouth with three or four indistinct papillæ; œsophagus 0.16 mm. long, with well-developed buccal cavity and two bulbs, the posterior of which is armed with three chitinous teeth; anus with protruding lips on right side of body. Male (Fig. 3541, B): 0.75–1 mm. long, 35 to 66 μ thick, with short recurved tail and two curved, conical spicules, 38 μ long. Female (Fig. 3541, A): 1–1.4 mm. long, 50–75 μ broad, with long slender pointed tail; vulva a little behind the middle of the body and on the right side; uterus double; eggs ellipsoidal, thin-shelled, 70 by 45 μ, segmentation advanced, embryo often hatched within body of mother; embryos at first with tapering tail, bulbous œsophagus, and chitinous teeth, soon changing to filariform stage.

Parasitic generation (Bavay's *A. intestinalis*) (Fig. 3539). Female only, hermaphroditic or parthenogenetic; length 2.1–2.2 mm., breadth 30–39 μ, body slightly tapering anteriorly, but terminated posteriorly by a short bluntly conical tail, with rounded and slightly dilated tip; mouth with three poorly developed lips (or none? Strong); œsophagus cylindrical, with no swellings, one-fourth the length of the body or more, distinguishable readily only in color from the intestine; vulva transverse in posterior third of the body; uterus with five to six (nine to twenty?) ellipsoidal eggs, 50–59, or 65–70 μ by 30–34, or 39 μ, and often joined in strings of two or three. The eggs are segmenting when laid, they develop rapidly and hatch before being ejected with the excrement. Embryos rhabditiform, 0.3–0.6 mm. long by 16–22 μ wide; first molt within twenty hours if in incubator.

Dr. Normand discovered the species in 1876, when examining microscopically the stools of soldiers returned from Cochin China, who were suffering from acute dysentery. Somewhat later he found at the necropsy of a soldier who had died from Cochin China diarrhœa, the other form of the species. Both of these forms were originally studied and described by Bavay. It was in 1883, before the connection of the two was established by Leuckart, who showed them to be phases in the life history of the same species. In life man harbors in the canal the one* form (*A. intestinalis* Bavay) and its young which, reaching the exterior with the fæces, may be transformed then into the other adult (*A. stercoralis* Bavay); the latter transformation may also take place in the intestine after death, as in cultures made in confirming these discoveries. Later authors have added many details, which may be summarized as follows:

The parasitic generation, which recalls a strongylid or a filaria in general appearance, produces eggs so abundantly that from an ordinary infection more than a million embryos may be evacuated in a single stool. The embryos (Fig. 3540, A) measure at hatching 0.2–0.24 mm. long by 12 μ broad, but develop so rapidly that those in the stools have attained a length of 0.30–0.60 mm. by a width of 16–23 μ. The embryos are characterized by a rhabditiform œsophagus, and under normal temperature they soon moult; and then, protected as if by a cyst in the larval skin, await more favorable conditions for further development. If kept, however, at a temperature of 25–35° C. they develop to sexual maturity in fifteen to eighteen hours; they copulate in thirty hours, and the females begin to lay at fifty to fifty-five hours.

After the first moult the structure of the embryos becomes more distinct, and one can see three or four oral papillæ and a buccal cavity, together with an anterior enlarged and median constricted region of the œsophagus, which is terminated by the œsophageal bulb, containing an apparatus for trituration composed of three chitinous teeth. The intestine which follows ends in a slightly protruding anus located on the right side. Also on the right, about one-third the distance from the bulb to the tail, is the whitish lenticular proton of the sexual system.

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* It is disputed whether the other form may very rarely be found under the same circumstances.

In most cases studied in temperate regions after a few days in culture, these embryos die or change form, becoming elongate and with more tapering tails, the œsophagus loses its teeth and enlargements and becomes a uniform cylinder; the embryos resemble young filariæ and have taken on the strongyloid form (Fig. 3540, B).

Only thirty to forty eggs are deposited by each female of the free generation (Bavay's *A. stercoralis*), which develop so rapidly as to approach the ovoviviparous condition; they hatch out young worms about 0.22 mm. long, in which the œsophagus manifests a distinct rhabditiform character. After the first moult, which occurs when they are about 0.35 mm. long, they acquire in from thirty to thirty-six hours the strongyloid appearance, in that the mouth shows four lips, the œsophagus is cylindrical and has lost its dental armature, the tail is shortened, and bears near its end two small lateral wings. At the end of eight days the free form can no longer be found in the cultures, and all the young have become strongyloid larvæ. If introduced into the intestine, these larvæ develop into the parasitic female, with which the cycle begins anew.

A remarkable modification of this, the normal life cycle of the species, was discovered by Grassi, who found that the development might be abridged since the rhabditiform embryos may transform directly into the strongyloid larvæ without the intervention of any free sexual generation. This direct development has been confirmed by Leichtenstern, who has observed it for weeks in succession, while at other times alternation with the free rhabditiform generation comes in. The causes of this transformation are unknown as yet; it must, however, be regarded as an important etiological factor, since the infection of man may be due to the accidental introduction of either sort of larvæ, or of the adult parasitic form. Stiles has suggested that this abbreviation is a step toward perfect parasitism.

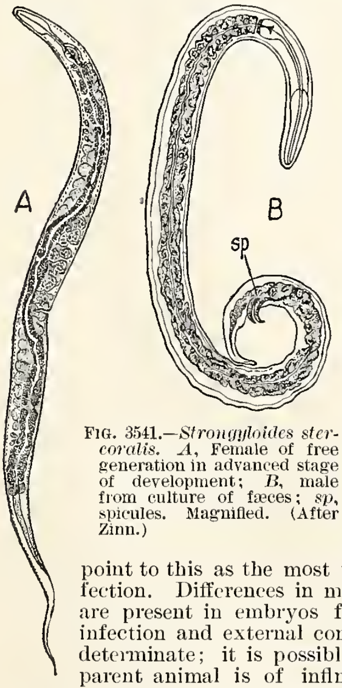

FIG. 3541.—*Strongyloides stercoralis. A*, Female of free generation in advanced stage of development; *B*, male from culture of fæces; *sp*, spicules. Magnified. (After Zinn.)

The method of introduction can only be inferred to be impure water or vegetables, salads, etc., which have been contaminated by human excrement. Although Normaud acquired the disease in Cochin China, while having refrained absolutely from drinking any but imported water, and was accordingly inclined to question the part played by water in its dispersal, yet in the absence of further evidence general considerations must point to this as the most probable source of infection. Differences in manner of development are present in embryos from a single original infection and external conditions seem to be indeterminate; it is possible that the age of the parent animal is of influence. Embryos with direct development are at least more resistant, and alone survive under unfavorable environment.

It has been claimed after culture experiments by Wilms that there are not two varieties of the parasite, one developing by the direct, the other by the indirect method, but that embryos from the same lot of eggs may develop in either fashion. Though the number of cases observed is probably too small for definite conclusions, it is striking that cases infected with the tropical strongyloids develop usually with the interpolation of the free sexual generation, while cases infected in temperate regions, both of Europe and America, manifest almost exclusively direct development. It should not be forgotten that there may be concerned here more than one species of closely related and heretofore confused forms, which would account for some of the apparently conflicting statements. Certain it is that the figures of the larvæ, given by various authors, do not agree in the form and proportions of the different regions in the œsophagus, which for individuals in the same moult are ordinarily regarded as constant, and an examination of the adult parasites, as figured by two most recent observers, Strong and Braun, shows numerous differences in detail, which can hardly be errors in observation.

The observations of Grassi, that the alternation of generations described above is not a necessary feature in the life cycle of this species, is still further of importance as explaining the enormous number of worms found in the intestine in some cases. Leuckart records an instance in which prodigious quantities of the worms were evacuated even a year and a half after leaving the locality of infection. Such evidence leaves little reasonable doubt of the multiplication of the parasite in the human alimentary canal, as in fact related species do so reproduce in other animals and as *Anguillula aceti* multiplies in the human bladder as noted above.

Distribution.—*Strongyloides stercoralis* occurs very widely. The entire tropical and subtropical zone of Africa, Asia, the Philippines, and the East Indies form apparently its original home, within which its occurrence is all but universal. It has also been recorded from Martinique, Brazil, Hawaii, and in Europe from Sicily, Italy, and Mount St. Gothard tunnel, Spain, Russia, and among brickworkers along the Rhine and in East Prussia. First reported in the United States by Strong, it has been observed and studied since then twice in Baltimore by Thayer, who showed its probable endemic character. For further data on its occurrence as well as for bibliography and discussion of previous cases consult the splendid paper by the latter author. Stiles has 5 further cases to be published soon.

Pathology.—At first the worm was regarded as the cause of the dysentery in which it was originally discovered and with which it is usually associated; more recent investigations have thrown some doubts upon this view. The rarity of the worm in the intestine at the outset of the disease, its abundance in stools of convalescents, its absence in cases which have freely bilious diarrhœa, and often in severe attacks of Cochin China diarrhœa, and finally its frequent presence in individuals enjoying normal health, all militate against the supposed pathogenic rôle of the species; and both Grassi and Leichtenstern go so far as to proclaim the species entirely innocuous, "innocent commensals of man."

On the other hand, its presence is not regarded by all authors as harmless, even though they do not regard it as the cause of the disease. Sonsino has found that in Italy excessive multiplication of the species may give rise to acute enteritis followed by dangerous anæmia. Golgi and others have observed epithelial lesions which they have attributed probably with justice to the action of this parasite. Its extraordinary multiplication in the human alimentary canal must contribute to the irritation of the mucosa and to the development of the lesions produced by the so-called Cochin China dysentery. Recent observations of Askanazy serve to demonstrate the pathological character of these worms, which he finds to be actual parasites of the intestinal wall in the duodenum and jejunum. Here they penetrate chiefly the mucosa, being often found in the epithelium of Lieberkühn's glands. They may penetrate to the muscular layer or rarely deeper than this. These migrations are in search of food, as the chyle-filled body of the worm shows; but no evidence was found to show that they ever suck the blood of their host.

The female deposits eggs in the galleries of the mucosa, which give rise to embryos that wander out into the lumen of the intestine. In Teissier's case it was claimed that these embryos had taken a different route and had entered the circulation, perhaps by way of the chyle tubes; their presence here was accompanied by high temperature, which abated with their disappearance three days later. More probably this case represents a double infection of *Filaria* with *Strongyloides*. The limited number of *Strongyloides* eggs found in the fæces is to be explained perhaps on their deposition deep in the tissue. More recently Strong has confirmed the presence of adults, eggs and embryos in the epithelium and in the cavity of the crypts of Lieberkühn, in which cases the epithelium is often atrophied and less frequently entirely gone. Infiltrations of small round cells were observed in some cases, but no marked inflammatory changes. This author believes that the parasite is not harmless, though not particularly dangerous; and he finds it capable of producing an intermittent diarrhœa with intestinal disturbances. It certainly causes some mechanical injury from its rapid movements.

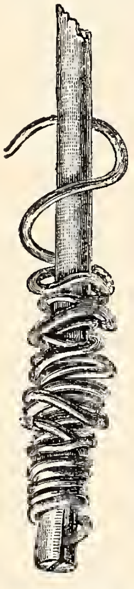

FIG. 3542.—*Filaria medinensis*, Rolled on Split Stick. (After Fedtschenko.)

Prevention.—The use of filtered or boiled water and abstinence from eating uncooked vegetables of any sort, as well as the destruction of stools from patients afflicted with the parasite, are evident measures suggested by the life history. Special mention has been made by various observers of the general immunity of natives in Cochin China toward both the parasites and the endemic dysentery, and it has been explained on the basis of their universal use of water boiled or treated with alum sufficient to precipitate the organic matter.

The hydrotactic tendency of the embryos is useful in diagnosis in cases in which they are present in small numbers, since in the centre of a fecal layer spread on a culture plate a small cavity can be made and filled with water; here the embryos collect and are easily found. In pure water the embryos of the free generation are apt to perish, perhaps through lack of food materials. Leichtenstern has also pointed out that a differential diagnosis between this species and *Uncinaria* is not difficult, since in fresh fæces the latter form appears only as eggs, the former only as embryos. The *Uncinaria* embryo is also easily distinguished from that of *Strongyloides*, since the latter has a short thin-walled oral cavity, hardly chitinized at all, and a large spindle-shaped sexual rudiment, 33μ long, while the former possesses a long, heavily chitinized oral cavity and a minute circular sexual rudiment, only 3μ long. If eggs are taken from the canal at a necropsy, those of *Uncinaria* are distinguishable from those of *Strongyloides* by the smaller size and thicker shell.

Treatment.—Turpentine and male fern have no apparent effect. In mild cases thymol with general tonic treatment is successful generally, but in severe infections nothing yet reported is of any apparent value.

A genus which offers evident affinities to both Strongylidæ and Filaridæ, but which is usually included in a separate family, the Gnathostomidæ, is represented among human parasites by a single rare species:

Gnathostoma siamense (Levinsen 1889.)—(Syn.: *Cheiracanthus siamensis* Lev. 1889.)

The genus is easily recognizable by the numerous spines which cover the entire body, or at least the anterior region. Several species occur in the Felidæ, and in swine and cattle. This form is known only by a single female specimen, length 9 mm., breadth 1 mm.; about the head eight circles of spines. The anterior third of the body alone is covered with spines, the anterior of which are three-pointed, and the posterior simple. The vulva lies behind the centre of the body.

The specimen was collected in Siam and came from a small tumor; when this disappeared there were found on the skin nodules the size of a pea, from one of which this worm emerged. The same symptoms were observed in two other cases, and in one of these five or six worms were expelled, but were not preserved.

Family of the Filaridæ.—Body greatly elongated, filiform; mouth variable, often papillate, sometimes with lips and even with a buccal capsule; œsophagus slender and without a bulb; male, with somewhat coiled tail and a single spicule or two unequal ones. Female, with double ovary and vulva near the anterior end of the body. Many species are ovoviviparous.

Filaria O. F. Müller 1787.—Very slender worms of nearly equal calibre throughout. Males notably smaller than the females, with coiled posterior end, which possesses in some cases alar appendages. Spicules ordinarily very different in size and form. Four preanal papillæ are almost constant; the number of postanal papillæ is, however, variable. Vulva always near the anterior end.

These forms are parasites of the serous cavities and subdermal connective tissue; in general the development, though not well known, appears to be indirect with an intermediate host from Crustacea or Insecta. Raillet justly remarks that for the physician this genus is a sort of "catchall" into which he throws all round worms, old or new, of which the structure is poorly known.

Filaria medinensis (Linnæus 1758)—(Syn.: *Gordius medinensis* Linn. 1758; *F. medinensis* Gmelin 1789; *F. dracunculus* Bremser 1819; *F. æthiopica* Valenciennes 1856; *Dracunculus medinensis* Cobbold 1864.)

Female: 30–100 cm. long (ordinarily 50–80), 0.5–2 mm. broad; body uniform in diameter, white or yellowish-brown; the anterior end smooth, rounded, with cephalic shield, and small mouth surrounded by six papillæ; alimentary canal atrophied in adult and with all other internal organs replaced by enormously developed uterus; vagina has disappeared. Uterus filled with larval filariæ, 0.5–0.75 mm. long and 15–25μ wide.

Male doubtfully observed, said to be much smaller than female, only 4–10 cm. long, found fixed to the female by its posterior extremity, about 14 cm. from the anterior end of the latter. If the observation is substantiated, the male follows the female into the tissues and perishes soon after copulation there. The vagina atrophies subsequently to this.

The so-called "guinea-worm" is the subject of the oldest records dealing with any parasite. Doubtless the fiery serpents which plagued the children of Israel in the wilderness were this species. The writings of the Egyptians and those of early classical times, as well as later authorities, make definite references to it. The Arabian physicians knew it well, and Rufus, of Ephesus, not only gives a good description of the disease and its cause, which he designates as a little snake, but recounts the commonly accepted opinion that "the Arabians suffer from it, and many strangers acquire the disease *if they drink the water*, for that is the chief cause."

Life History.—The adult female is met with in the connective tissue, particularly of the legs and feet. It appears here in eighty-five per cent. of all cases, and pierces the derma; a blister forms in the epidermis over this orifice, and on rupturing shows a small ulcer at the centre of which is a minute opening. If cold water is dashed on the surface here, a drop of a milky fluid exudes or a small tube (the uterus?) is protruded and bursts, setting free the opaque fluid. This fluid contains multitudes of embryos 0.5–0.75 mm. long and 15–25μ wide; they are flattened, terminate in a long pointed tail, and have a striated cuticula and a complete alimentary canal. They swim actively but intermittently, and live six days in pure water, but from two to three weeks in muddy water or moist earth.

As may be followed experimentally they enter the body cavity of small aquatic animals (*Cyclops*, Fig. 3543) through the joints in the exoskeleton, and there with two or three moults, occupying five or six weeks, they metamorphose into a more cylindrical form with a tripartite posterior end. The further life history is unknown. Fedtschenko tried to infect cats and dogs with these infested *Cyclops*, but without result. Manson and Blanchard have successfully repeated these experiments. Some further changes may easily be necessary before the parasite is fitted for its final host, which may be cattle, horse, dog, wildcat, or jackal as well as man.

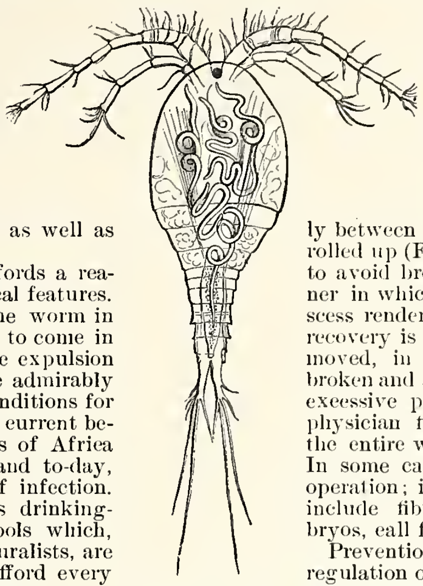

FIG. 3543.—Embryos of *Filaria medinensis* in body cavity of *Cyclops*. (After Fedtschenko.)

The life history, as given above, affords a reasonable explanation of some biological features. Both the preferential location of the worm in legs and feet which are most likely to come in contact with standing water and the expulsion of the embryos on such contact are admirably adjusted to secure for the young conditions for further development. It is a widely current belief among natives in different parts of Africa and Arabia, both in ancient times and to-day, that drinking-water is the source of infection. In the majority of infected districts drinking-water is obtained from surface pools which, according to the observations of naturalists, are swarming with *Cyclops*, and hence afford every opportunity for the spread of the disease.

Distribution. — The guinea-worm is rather widely distributed in tropical and subtropical countries. Most abundant in Deccan (India) and on the west coast of Africa, where in some seasons from one-half to nearly the entire population is affected, it is found more or less from India westward through Southern Asia and tropical Africa, and in a limited area of Brazil, where its introduction may probably be attributed to the slave trade. In Curaçoa and Surinam, where it was formerly endemic, and where it was no doubt introduced with negroes, it has now entirely disappeared. Records of its occurrence in Europe and North America are from natives of the infected area or visitors to it, and though frequently introduced it has never gained a footing in either place. Records of its occurrence in Africa and Arabia are found in historical and medical works of all ages. It is also known to occur in Persia, Turkestan, and Hindustan.

Pathology.—The seat of the adult females is the subcutaneous connective tissue, and they occur most commonly in the lower extremities, especially in the foot and ankle, but have been found in the arm, tongue, eyelid, scrotum, perineum, and trunk. As many as five or six in a single host is not uncommon. The presence of the worm is not detected ordinarily until it approaches the skin, where it produces a swelling, at first painless but later painful, and ultimately a running sore. Of itself the worm may be considered comparatively harmless, but the complications incident to a tropical climate often bring about excessive suppuration and gangrene, such as to necessitate amputation of the part infected, or even to be followed by death. The worm is sometimes expelled spontaneously, but in the majority of cases it is extracted by what is known as the Soudanese method. The end of the worm is seized firmly between two splints, on which it is gradually rolled up (Fig. 3542), great care being exercised to avoid breaking the slender body. The manner in which the worm is coiled up in the abscess renders the operation very slow, and while recovery is rapid when the entire worm is removed, in those cases in which it has been broken and a part left behind, the result has been excessive pain and often fatal gangrene. The physician finds it more satisfactory to remove the entire worm at once by a simple operation. In some cases complete cure follows a single operation; in others subsequent growths, which include fibrous tissue with numbers of embryos, call for further operative interference.

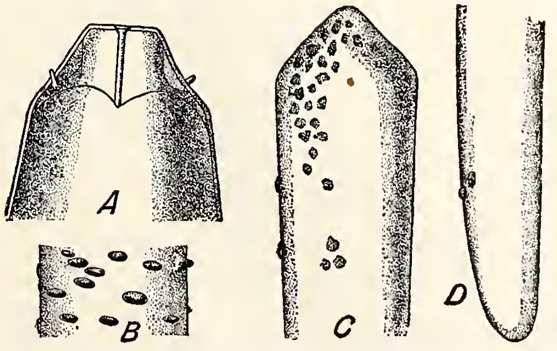

FIG. 3544.—*Filaria loa*. *A*, Head of male; *B*, mid body of male with cuticular bosses; *C*, head of female with bosses; *D*, posterior end of female with two bosses. Magnified. (After Blanchard.)

Prevention. — Apparently the satisfactory regulation of the supply of drinking-water will prove the means of stamping out the disease. Surface water is particularly suspicious on account of the large number of *Cyclops* likely to be present.

Filaria loa Guyot 1778.—(Syn.: *F. oculi* Gerv. et v. Ben. 1859 (nec. v. Nordm. 1852); *Dracunculus oculi* Diesing 1860; *Dr. loa* Cobbold 1864.)

Female 30–40 (rarely 70) mm. long, by 0.5 mm. broad, of cylindrical form (Fig. 3544) with anterior end blunt, posterior, straight, pointed; cuticula, transparent, yellowish, not striated but marked with minute, chitinous bosses irregularly distributed; uterus bifid, coiled; eggs 30–35 by 20–25 μ; when deposited containing embryos 210–250 μ in length.

Male: 20–30 mm. long, 0.3–0.45 broad; cuticula not striated, but with small papillæ except on first and last fifth; mouth without papillæ; tail (Fig. 3545) slightly incurved, with lateral wings and five ventral papillæ on each side, three being preanal and the first the largest; spicules two, short, unequal.

It was first observed in 1770, though a print of 1597 seems to show an operation for its removal. Nearly thirty cases are now on record; most of these are only notes, but recent descriptions of Ludwig and Blanchard have made its appearance and structure known. The earlier authors were inclined to regard it as identical with *F. medinensis*, but its specific distinctness maintained by others is now clearly demonstrated. Even if the immaturity of specimens eliminates the difference in size, the smooth striated cuticula of the guinea-worm will serve to separate it at once on careful examination from *F. loa* with its non-striated, embossed surface. The embryos differ also.

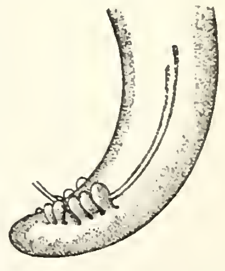

FIG. 3545. — Tail of Male *Filaria loa* with Spicules and Papillæ. (Author's specimen.)

In distribution *F. loa* is limited to an area on the west coast of Africa (Guinea, Gold Coast, Gaboon), where it is not uncommon, and cases reported from other regions, which are largely among slaves of earlier days, have been those of persons who had come more or less recently from that region. Such are on record from Brazil, Trinidad, St. Domingo, France, England, and the United States.

Naturally the majority of records affect negroes, but physicians in Africa maintain that the parasite attacks blacks and whites alike, and the number of cases reported among missionaries supports this view. One of the latter has recently been reported in the United States by Ward and Milroy.

Life History.—From the scattered facts on record Blanchard has outlined the course of development as follows: Introduced into man in the larval form with drinking-water, the form becomes adult in the alimentary canal. Either before or after copulation it penetrates the tissues where its development is slow, as shown by a residence of from four to ten years or more in the body. It appears beneath the conjunctiva of the eye or the skin at the last phase of its existence, but it may reach the surface of the body without having acquired its full development. That unlike *F. medinensis* it does not deposit eggs in dermal abscesses is clear from the entire absence of pus formation and of eruption in cases of its occurrence. It is a prisoner in the body, and the embryos must escape independently of the mother. They probably penetrate the blood, and are drawn from it by some blood-sucking parasite, from which in some unknown way they reach running water and in it a new host, or are inoculated directly when the intermediate host is feeding. Manson has conjectured that the well-known *F. diurna* is the larva of *F. loa*, with which it agrees in geographical distribution. The opinion is generally accepted among inhabitants of the affected region that the source of infection is to be found in drinking-water.

Pathology.—The parasite is an active migrant through the connective tissue, but comes often into the region of the orbit. Its appearance in the tissue of the lid or beneath the conjunctiva is made known ordinarily by itching or even by slight pain which may disappear with the withdrawal of the worm, only to recur with its subsequent return at irregular intervals of days, weeks, or even months. An individual has been seen to pass rapidly from the one eye to the other over the bridge of the nose. In one case only has an immature specimen been found actually within the eye. In addition to itching, transient œdematous swellings accompany its appearance in various parts of the body. Fugitive tumefactions, known as Calabar swellings, are not uncommon in lower Nigeria. They are half the size of a goose egg, painless, sudden in appearance, disappearance, and recurrence, and may be found in any part of the body. They are thought to be produced by rubbing when a *F. loa* approaches the surface.

Treatment.—The negroes drive it from the eye by dropping a grain of salt into the conjunctival sac or by extracting the worm with a thorn. Deftness in operating is necessary, and if after cocainizing the eye the worm be grasped with a pair of forceps, a cut in conjunctiva or lid gives an opening through which it usually starts to escape, or may be withdrawn by a second forceps.

Filaria volvulus Leuckart 1893.—Body tapering uniformly, head rounded. Male 30–35 cm. long, 40–140 μ in diameter, tail incurved; one postanal, two adanal, one preanal papilla on each side, two spicules 0.08 and 0.177 mm. long. Female 40–70 cm. in length. Embryos 250 μ long, 5–6 μ wide, resembling *F. nocturna* and *F. diurna*, but shorter and thicker and without sheath, head rounded, tail very sharp, clear spot in anterior fourth of body.

Leuckart received two dermal tumors from Gold Coast negroes containing several worms coiled in a ball and surrounded by a fluid containing embryos. A somewhat similar tumor excised from the arm of a French soldier, who had been in Dahomey, showed that the worm occupied a lymph vessel and was surrounded by a mass of connective tissue. Its identification as the same species has been questioned. Prout has recently described two other cases from Sierra Leone. Like *F. loa*, it is viviparous and found in subdermal tissue; but unlike that species it is sedentary and produces a circumscribed subcutaneous tumor.

F. conjunctivæ Addario 1885.—(Syn.: *F. palpebralis* Pace 1867, nec Wilson 1844; *F. peritonei hominis* Babesiu 1880; *Filaria inermis* Grassi 1887.)

Female: Length 10–16 cm., width 0.5 mm.; cuticula striated not embossed or papillate; mouth terminal, unarmed, vulva near anterior end; uterus double, with eggs and embryos measuring 350 by 5.5 μ. Male unknown.

Dubini first found this species in Sicily in a tumor of the conjunctiva, and it has been recorded as a human parasite also in Italy and Hungary. The species is, according to Grassi, a normal parasite of the horse and ass, and is only occasional in man.

Filaria lentis Diesing 1851.—(Syn.: *Filaria oculi humani* von Nordmann 1832.)

With the case of von Nordmann, in which immature nematode worms were found in the lens, have been associated various poorly known and often doubtful cases of later observers, in several of which it is probable that the object was a vestige of a vessel or filament and not a filaria. In three cases the parasite was in the lens, in three also in the vitreous humor, and in two in the aqueous humor. The most recent, by Drake and Brockman, at Madras, has been assigned by Blanchard to *Filaria equina*, which is abundant in India. The character of other species is likely to remain permanently doubtful. Some of them are very likely young forms of the preceding species, *F. inermis*.

Filaria restiformis Leidy 1880. Length 66 cm., width at head 0.375 mm., at centre 1.5 mm.; anterior end pointed, posterior blunt; mouth without papillæ; œsophagus 1.125 mm. long.

Passed in West Virginia from the bladder of a man, fifty years of age. The patient had been suffering some days from hæmaturia. Railliet regards it as evidently a pseudoparasite. While it was not extracted by the attending physician, he maintained that no doubt existed as to the correctness of the patient's statements that the worm had actually been passed.

Filaria hominis oris Leidy 1850.—Length 14 cm., width at head 0.1 mm., at centre 0.38 mm. Mouth terminal, posterior end provided with an epidermal spine, 0.05 mm. long.

Leidy found the single specimen in the collection of the Philadelphia Academy labelled, "Obtained from the mouth of a child," and queried if it might be the young or the male of *F. medinensis*. Leuckart shared the opinion which has, however, been questioned by some later investigators.

F. labialis Pane 1864.—Length 30 mm.; pointed anteriorly; mouth with four papillæ, posterior end slightly inflated; vulva in posterior tenth; uterus double, but in posterior branch rudimentary.

A single specimen only from a pustule on the upper lip of a man in Naples, Italy. Not reported since 1864.

F. lymphatica Treutler 1793.—(Syn.: *Hamularia lymph.* Treutler 1793; *Filaria hominis bronchialis* Rud. 1819; *F. hominis* Dies. 1851; *F. lymph.* Moq.-Tandon 1860; *Strongylus bronchialis* Cobbold 1879.)

Length about 26 mm.; brownish spotted with white; transparent and pointed anteriorly; thickened and blunt posteriorly; two short spicules.

First found in 1790 in the hypertrophied bronchial ganglia of a man of twenty-eight years of age; it has been reported since then by Brera and by Zürn, who discovered another specimen at Geneva in 1879, under conditions like those of the first case. The view of Diesing and Weinland, that it was probably *Strongylus longevaginatus* (= *S. apri*) is improbable according to Railliet, who views it as a male of *F. inermis*. The view of Braun that it is *F. equina*, a common parasite of horse and ass in Europe, seems more probable.

Filaria immitis Leidy 1856.—Mouth with six papillæ. Male: 12–18 cm. long, 0.7–0.9 mm. wide; posterior end with low lateral wings and eight preanal as well as nine to ten postanal papillæ; posterior end rolled in several turns like a corkscrew, spicules unlike. Female: 25–30 cm. long, 1–1.3 mm. wide, posterior end shortly blunt; vulva in posterior fourth; ovoviviparous embryos 0.28–0.30 mm. long and 5 μ wide, with a greatly attenuated posterior extremity.

Originally found by Leidy in the heart of a dog, it is now known to inhabit the entire venous system. The embryos are to be found in the peripheral circulation during the period of rest. With growth they retire to the larger vessels and escape from the kidneys or in excrement. Their normal method of exit is unknown. The parasite is most common in dogs living in the open.

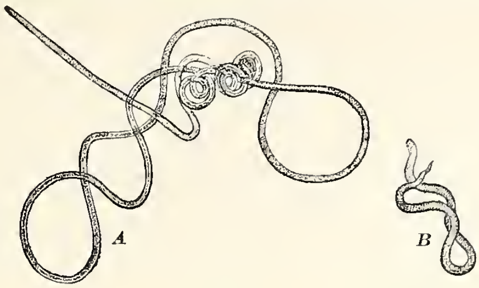

Fig. 3546.—*Filaria Bancrofti.* *A*, Adult male × 7.5. *B*, Embryo from hydrocele fluid × 200. (After Lothrop and Pratt.)

The parasite is common in the United States, especially in the South and in South America. It seems to be very abundant in China and Japan, and is reported also from Italy, France, Germany, and Denmark.

As Moniez has shown, Braun was apparently in error in citing Bowlby as authority for the occurrence of this species in man; and Braun's own case is too uncertain in determination to be accepted as evidence in absence of other instances. If *F. immitis* is even occasionally a human parasite, it should be found as such in the United States, where it occurs commonly. No case has been found on record.

Filaria Bancrofti Cobbold 1877.—(Syn.: *Trichina cystica* Salisbury 1868, non Filaria cystica Rud. 1819; *F. sanguinis hominis* Lewis 1872; *F. sang.-hom. ægypt.* Sonsino 1874; *F. dermathemica* Da Silva Araujo; *F. Wuchereri* da Silva Lima 1877; *F. sanguinis hominis nocturna* Manson 1891; *F. nocturna* Manson 1891.)

Body elongated, white, opaque, very delicate, showing tendency to coil; cuticula without transverse striation, anterior end slightly thickened, without lips or papillæ, posterior end rounded. Male 35–40 mm. long; 0.1–0.12 mm. broad, head 51 μ, neck 43 μ, in diameter; œsophagus 0.13 mm. long; tail (Fig. 3547) slightly bent, 1 mm. long; papillæ undescribed; spicula 0.2 and 0.6 mm. long. Female 75–95 mm. long, 0.21–0.28 mm. broad, head 68 μ, neck 51 μ in diameter, vulva 0.72–1.27 mm. from head, anus 0.282 from tail. Eggs 25–28 μ or 35 (Lothrop and Pratt) by 15 μ. Embryos 0.127–0.2 mm. (or 0.2–0.33 mm.) long by 8–10 (7–11) μ broad, with unstriated cuticula, but enveloped in a delicate sheath (Fig. 3546, *B*).

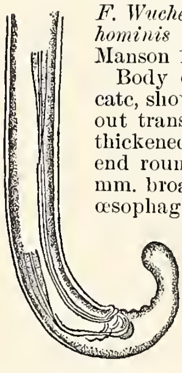

Fig. 3547.—Tail of Male *Filaria Bancrofti.* Magnified. (After von Linstow.)

Although first reported as early as 1863 by Demarquay, this form has been very generally confused with other species of the group, especially *F. Magalhaesi*, and even now only a little can be given beyond the data contained in the general characteristics which are taken from Maitland and Manson's account, and from that of Lothrop and Pratt. The discrepant measurements given by different authors are due, in part at least, to the fact that different species were under consideration.

The male (Fig. 3546, *A*) is much shorter than the female, and the posterior end exhibits a strong tendency to twist like a tendril. Both sexes manifest a proclivity to curl into a knot, and various observers note the difficulty of disentangling the individual worms from such a mass. In the female, which alone has been examined, the anterior end is traversed by four deep grooves, giving the transsection much the form of a maltese cross. The thick-walled vagina extends posteriorly a short distance from its external orifice, and splits into two thin-walled uterine tubes, which occupy the entire cavity of the body, forcing the intestine against the muscular wall at one side. These tubes are filled with ova and embryos in all stages of development. The smaller embryos are coiled within a thin structureless chorion. Preserved specimens may assume a brownish tint, owing to a change in the color of the uterine walls.

The embryonic filariæ in freshly drawn blood or in hydrocele fluid are rounded at the anterior end and pointed at the posterior. Though in constant motion, twisting and coiling, they never (?) exhibit a true progressive movement. In freshly drawn blood they are covered by a delicate sheath, which is indistinguishable normally except as a flagellum following the tail at some distance, 0.3–0.4 mm. (Fig. 3548); rarely, when the movement of the body is reversed, this disappears from the tail and becomes evident at the head (Fig. 3548, *A*). It is evidently the collapsed sheath, which Manson regards as a vitelline membrane, and in such specimens as have undergone endosmotic changes it appears like a distended sac enveloping the entire worm; such an appearance, though frequently figured, is entirely unnatural. The embryos of other species, *e.g.*, *F. immitis*, are without this sheath. These embryos may be kept alive five or more days in a cover-glass culture of blood, and after forty-eight hours many empty sheaths may be observed. Attached to the tip of the head is a minute spine, which at times is protruded in rapid succession with a peculiar "pouting" movement.

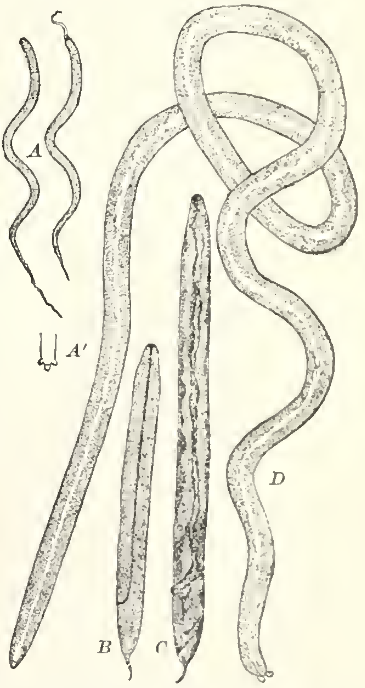

Fig. 3548.—Metamorphosis of *Filaria Bancrofti* in Thorax of Mosquito. *A*, Just ingested; *A′*, posterior end; *B*, five days old; *C*, ten days old; *D*, sixteen days old. (After T. L. Bancroft, except *A′* after Manson.)

Life History.—The female is viviparous, and the embryos, which are produced in enormous numbers, are evacuated into the lymph stream and ultimately pass from it into the blood current, where they are often found in extraordinary abundance. They measure 0.2–0.33 mm. by 7–11 μ (Lothrop and Pratt, 0.26–0.3 mm. by 6–8 μ). Twelve hours after being taken into the stomach of a mosquito one finds side by side free embryos and empty sheaths. By the next day the embryos have traversed the wall of the stomach and are in the thoracic muscle. At the end of eleven days they are 20–25 μ broad and more than 580 μ long. At seventeen to eighteen days they begin to leave the muscles and migrate into connective tissue in front of the prothorax. Such larvæ are more slender than before, 18–20 μ in diameter. These larvæ show an alimentary canal with œsophagus well differentiated and rudiments of the reproductive apparatus. While some remain in muscles even up to the fiftieth day, the most are gone. By even the twentieth day larvæ have penetrated the head and proboscis in sections of which they appear crowded into the cavity headed toward the point (Fig. 3549). Like the malarial organism they are inoculated directly. The last stage of development occurs in the skin; they become adult and copulate there; thus the variable position of lesions of elephantiasis are explained. In *Anopheles* James finds that the transformation requires only from twelve to fourteen days, and the activity of the embryos does not cease. According to the same author the broad inactive form measures 71–53 μ long and the slender active form 151–132 μ long and 2.6 μ broad; in this latter stage the œsophagus is two-fifths and the tail one-third of the entire length.

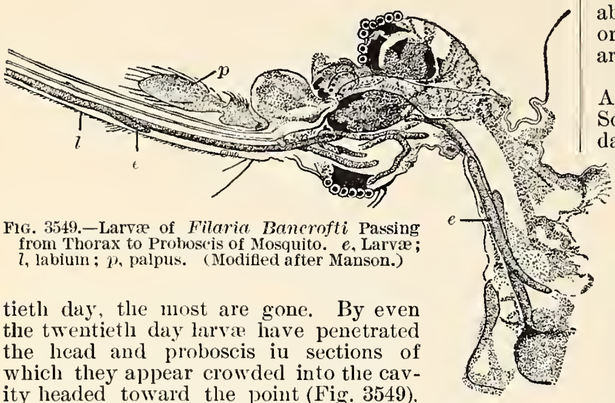

FIG. 3549.—Larvæ of *Filaria Bancrofti* Passing from Thorax to Proboscis of Mosquito. *e*, Larvæ; *l*, labium; *p*, palpus. (Modified after Manson.)

Bancroft and Manson suggested almost simultaneously that the mosquito might serve as a carrier of the embryonic filariæ in the blood. Manson, however, first observed the changes which these embryos undergo in the mosquito. He allowed mosquitoes to suck the blood of filarial subject, and found at first that the embryos are within a delicate sheath or membrane, apparently almost structureless; later, there becomes evident a marked transverse striation, and the sheath is ruptured by the worm forcing its cephalic end against it. Once free from the sheath, the embryo bores through the stomach wall of the insect and wanders into the thoracic muscles. The embryos which emigrate to the thoracic cavity do so as soon as they are withdrawn from the human host; those found some hours later in the mosquito's stomach are such as by immaturity or injury are not destined to metamorphose, and changes in such are retrogressive.

According to one view the worm escapes by boring its way out at the time the mosquito is depositing her eggs on the water, or by breaking out from dying mosquitoes which fall into a pool, and that the infection of the human host is brought about by drinking such water as contains well-developed embryos. It is further supposed that these young worms then bore their way through the human intestinal wall and attain maturity at some suitable point. Copulation here is followed by the production of swarms of embryos. In objection it may be urged that Bancroft has shown water to be fatal to the embryos in the course of three or four hours, and that hence it cannot be the medium by which they reach the human subject. He also says the embryos never escape naturally from the mosquito's body even if in water. The other hypothesis as to later development is that the infection takes place when the mosquito containing the fully developed embryos is sucking blood, and Bancroft has proved the migration of such embryos from the thoracic muscles into the labium, from which he believes they escape at a definite point at the tip to penetrate the body of the new host. Grassi believes that the larvæ escape from the bent labium in the act of biting by rupture of the cuticula. This part of the life history has not been cleared up as yet.

In the transmission of embryos certain species of mosquito only are culpable; among such are *Culex fatigans* in Australia, *Anopheles Rossii* in India, probably also *Anopheles musivus*; this genus James regards as the proper intermediate host, since in it the development is more rapid. In case the embryos are taken up by any unsuitable species of mosquito they are digested in the stomach; or if a few individuals succeed in wandering out, they are absorbed in the muscles.

Distribution.—Tropical Asia, Africa, America, and Australia are all infected. In Samoa and some other South Pacific Islands this parasite is particularly abundant, as much as fifty per cent. of the population being infected.

The first mention of this parasite in the United States was made by Salisbury in 1868, who found the ova in the urine. Some years later (1886) Guiteras called attention to the presence of the embryos in the South, reporting four cases from Key West and one from Charleston, S. C. Only a little later De Saussure published a clinical history of twenty-two cases, also from Charleston. Since then many cases have been reported in the Gulf and South Atlantic States, many of which have been undoubtedly imported, but indigenous cases are not wanting, and one concerns a woman who had always lived in Pennsylvania. The last account by Lothrop and Pratt gives a most extensive and valuable study of two cases in Boston imported from the Barbadoes, and includes important new data on the characteristics of the adult worms.

Pathology.—The adult worm was first found in 1876, by the elder Bancroft, in a lymphatic abscess of the arm and subsequently in a hydrocele. The two sexes are found coiled together, and probably live for some time. Since then this discovery has been abundantly confirmed. Manson has shown that the species normally occurs in the lymphatic vessels, and that the embryos, as well as the adults, rarely also gain the circulation by way of the thoracic duct. The embryonic blood filariæ were first observed by Demarquay, of Paris, in a man from Havana, who was suffering from chylocele. The name *F. sanguinis hominis*, first used for these embryos by Lewis in India, has been applied to several different embryos, which Manson has distinguished by appropriate names. Whether they belong to different species or are stages of development in one or two forms is still unsettled, though I am inclined to accept their specific independence. Such embryos have been reported from urine, tears (?), and secretion of the Meibomian glands as well as from the blood in cases of chyluria and elephantiasis, and also in apparently healthy individuals. In the Barbadoes nearly thirteen per cent. of the persons examined were infected, and yet two-thirds of the infected cases manifested no external sign of the disease.

Manson was also the first to establish the periodicity of the embryos, as those of this species appear in the blood toward evening, increase in numbers during the night, and disappear in the morning. Manson views the "filarial periodicity as an adaptation of the habits of the filaria to those of the mosquito, the intermediary host indispensable to the future life of the parasite." But since it has been shown that by reversing the period of sleep the habits of the embryo filariæ may be reversed also, the explanation of von Linstow appears more probable, namely, that the tonus of the capillaries is reduced during sleep; and thus the embryos, which are too large to enter them during the day, find entrance possible owing to the increased size of the vessels. Manson found the embryos massed in large arteries and irregularly scattered through the capillaries in the day time.

The presence of embryos in the blood is evidence of the parasitism of the adult in some part of the lymph system. The duration of life of both adult and larvæ is entirely unknown; for the former, however, it is certainly several years. So far as known the embryos do not bring about pathological changes, though leucocytosis with an increase of eosinophiles is noted in early stages, to disappear later. The adults occlude large lymphatics and produce lymph stasis with resulting dilatation of the lymphatics. The clinical manifestations depend upon lymphatic obstructions and give rise to both general symptoms and local, which latter vary widely according to the part involved and to possible modification by infective processes.

An estimate has been made of from forty to fifty millions of embryos in the blood of a single man, and yet the individual suffered no apparent effect. It must be said, however, that the results of the parasite are brought about gradually; they are primarily a varicose condition of the lymphatics, giving rise to various conditions, such as chyluria, varicose inguinal glands, lymph scrotum, chylocele, lymphangitis, elephantiasis (*q. v.*). In the latter it is probable that the obstruction to the flow of the lymph produces mechanically the distention and excessive growth of such parts as arm, leg, scrotum, which is characteristic of the disease.

For examination Manson recommends a thick film of blood drawn at 8 to 9 P.M., when the embryos are most numerous. Fixing is unnecessary and the stain (fuchsin, gentian violet) is made by adding a few drops of an alcoholic solution of the dye to a watch glass of water. Overstaining is reducible by dilute acetic acid.

Prevention.—The protection of drinking-water from contamination by mosquitoes is strongly to be advised, and the case of the Friendly Islands is cited as evidence of the value of this measure. There forty per cent. of the males are affected by filariæ, all the people drinking from open pools; but the chiefs who have closed-water tanks rarely acquire the disease. It may, however, be urged in favor of mosquito inoculation that the chiefs are also least subject to mosquito bites. In any event, the protection of drinking-water and the destruction of useless pools will certainly reduce the number of mosquitoes, and consequently the extent of the disease, whether transmitted through drinking-water or by direct inoculation of a mosquito.

It must be noted that the presence of an infected individual is a distinct menace to the health of a community, since the widespread distribution of mosquitoes capable of acting as the intermediate host insures the possibility, and under some circumstances the certainty, of wider transmission of the disease. There is little doubt that the cases recorded from the Southern United States are primarily traceable to such introduction from the West Indies. The same explanation lies near at hand for those occasional cases which have been recorded in various localities, both here and abroad.

Filaria Magalhaesi R. Blanchard 1895.—(Syn.: *F. Bancrofti* Magalhaes 1892 *nec* Cobbold 1877.)

Body slender, elastic, resistant; cuticula heavy, cross striated. Female, 155 mm. long, 0.33 mm. broad at head, 0.285 mm. at neck, 0.7 mm. in maximum; vulva 2.56 mm. from cephalic extremity. Male, 83 mm. long, 0.407 mm. broad; tail with double spiral, on each side four preanal and four large postanal, papillæ of mulberry form (Fig. 3550); smaller (?) spicule 0.23 mm. long, longer unknown. Eggs 38 by 14 μ; embryos 0.3–0.35 mm. long and 5 μ broad with transversely striated cuticula.

Of this form Magalhaes discovered in Rio Janeiro two adults in the left cardiac ventricle of a man in whose blood embryonic filariæ were also present. It was at first wrongly assigned to *F. Bancrofti*, from which it is easily distinguished by the above characteristics. Like all Nematoda living in the heart the cuticula is tough to resist the powerful blood pressure, the body being like catgut, whereas *F. Bancrofti* is delicate and easily torn. The proportions of embryos and adults also differ materially.

The life history is unknown.

F. perstans Manson 1891.—(Syn.: *F. sanguinis hominis minor* Manson.)

The embryos, which have been known for some time, are found in the blood at all hours. They have no sheath, and measure only 0.18–0.23 mm. long by 4.5 μ broad, being thus much smaller than those previously described. Their continued presence in the capillaries may be due to this fact. The head is armed with a minute, exceedingly delicate filiform spine set on a papilla; this structure may be protruded and retracted rapidly. The embryo not only wriggles actively, but also travels about very rapidly. It is not numerous, but may be found in company with *F. nocturna* and *F. diurna*.

The adult was found by Daniels in a native of British Guiana, in whose blood both blunt- and sharp-tailed (*F. Ozzardi*) embryos were present. A male and a female lay in subperitoneal connective tissue. Manson also found an adult in one case of "sleeping sickness." Among the negroes on the west coast of Africa from one-third to one-half are infected, and most such show the earlier symptoms of this disease in nearly all cases of which *F. perstans* is present. Yet this parasite is found in apparently healthy individuals, so that its etiological relation to the disease mentioned is still a matter of doubt.

F. Ozzardi Manson 1897.—Male, 45 mm. long, 0.06 mm. broad; female, 70–80 mm. long by 0.12 mm. broad. Embryos in blood, without sheath, sharp-tailed, 0.173–0.240 mm. long by 4–5 μ broad.

The embryos were originally reported from the blood of Carib Indians from British Guiana, and were present in about fifty per cent. of the cases examined. At first both sharp- and blunt-tailed embryos were found together and were regarded as developmental stages of one species. Daniels found adults, chiefly females, in the mesentery, and in fat at various points in the peritoneal cavity; and in a later case two sets of adults, the one which is regarded here as belonging to this species, and the other, which was viewed by Manson as *F. perstans*, to which the blunt-tailed embryos are also assigned. The relation of the adults to these embryos is still a matter of considerable doubt.

In addition to the foregoing there are also several species of *Filaria*, known only by the embryonic form which inhabits the blood. While von Linstow regards them all as developmental phases of one species, I cannot concur in a conclusion so widely at variance with their differences in structure, habits, and distribution. They may be briefly noted as follows:

Filaria diurna Manson 1891.—Only free embryos of this species have been observed. They were found in the blood of negroes from the west coast of Africa. They appear in the peripheral circulation about 8 A.M., increase in numbers until noon, and decrease later, to disappear by 9 P.M. The periodicity was maintained for some weeks. As adults of *F. loa* were found in one of the cases, Manson regards it as likely that *F. diurna* is the larval form of that species.

Filaria Demarquayi Manson 1891.—The embryos of this species were found in the blood of apparently healthy natives of St. Vincent, and later also of St. Lucia, West Indies, and of New Guinea. They have also been reported very recently from other localities in the West Indies. They resemble the embryos of *F. Bancrofti* in general appearance; they are, however, only half so large (in dry smears) and they are without a sheath. Their presence in the superficial capillaries is constant day and night.

For convenient reference the characteristics of the blood filariæ may be given here in tabular form (p. 216) so far as they have been determined.

Filaria romanorum-orientalis Sarcani 1888 is a species observed in the blood of a Roumanian woman. The parasite measured 1 mm. long by 0.03 mm. broad, and had an alimentary canal and well developed sexual organs.

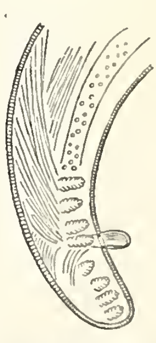

FIG. 3550.—Tail of Male *Filaria Magalhaesi*. Magnified. (After von Linstow.)

Family of the Trichocephalidæ. Body extremely elongated with two distinct regions, the longer anterior very slender and the shorter posterior more or less enlarged. Œsophagus very long, anus terminal. Males sometimes without a spicule, more often with a single simple one which possesses a sheath. Female with sim-

Characteristics of Blood Filariæ.

Species	*F. diurna*	*F. nocturna*	*F. perstans*	*F. volvulus*	*F. Demarquayi*	*F. Ozzardi*
Length	0.300 mm.	0.300 mm.	0.230 mm.	0.250 mm.	0.205–0.210 mm	0.17–0.24 mm.
Breadth	7.5 μ.	7.5 μ.	4.5 μ	5 μ	5 μ	4–5 μ.
Sheath	Present	Present.	Absent	Absent	Absent	Absent.
Head	?	Six-lipped armature	Papillated	Rounded	Retractile spine	
Tail	Sharp	One-fifth taper (sharp?).	Truncated.	Sharp, one-fifth taper.		Sharp.
Body	Central granular mass.	Indistinct central granular mass.	No central granular mass.	Central granular mass.		
"V" spot	Present.	Present	None	Clear spot	Present, 0.052 mm.	

ple ovary; vulva at junction of the two regions of the body; eggs with peculiar translucent plug in the shell at each pole. Development direct and without ecdysis.

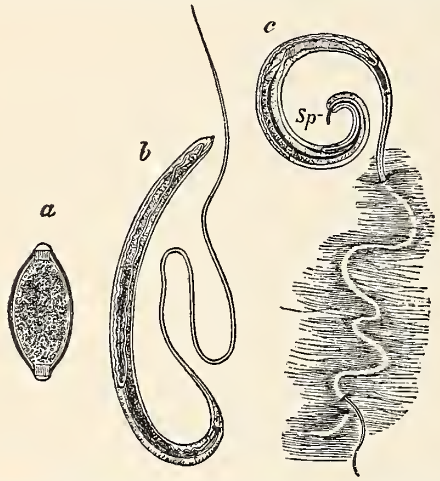

Fig. 3551.—*Trichocephalus trichiurus.* *a*, Egg; *b*, female; *c*, male with anterior end embedded in mucosa; *sp*, spicules. (After Claus.)

Of the half-dozen genera only two are important here, but they include two of the commonest and the most feared of human parasites.

Trichocephalus Goeze 1782.—Anterior region very long and filiform; posterior region, which contains the intestine and reproductive organs, short, sharply set off from anterior and markedly inflated. In the male it is rolled into a spiral; one spiculum with infundibuliform sheath. In the female the posterior regions are lightly bent, but not in a spiral. Parasitic in the large intestine and cæcum of mammals.

Trichocephalus trichiurus (L. 1771).—(Syn.: *Ascaris trichiura* L. 1771; *Trichocephalos* Goeze 1782; *T. hominis* Schrank 1788; *T. dispar* Rud. 1801; *Mastigodes hominis* Zeder, 1803.)

Male, 40–45 mm. long, with strongly attenuated anterior region comprising three-fifths of the total length. Spicule single, 2.5 mm. long, located in a spinous protractile sheath; posterior region in a flattened spiral. Female, 45-50 mm. long, with attenuated anterior region two-thirds of total length. Eggs, 51–53 μ long by 21–23 μ wide, brownish, thick-shelled, with polar knobs, and deposited before cleavage begins (Fig. 3551).

The striking appearance of this genus, a single species alone of which is parasitic in man, is due largely to the regions of the body. The filiform region contains only the œsophagus, leaving the remainder of the alimentary canal and all the reproductive organs for the greatly enlarged posterior region in which the transparency of the body wall permits one to recognize the various structures even in the living worm. The orifice of the vagina lies near the level of the transition from œsophagus to mid-gut.

Life History.—The eggs are produced in large numbers, four hundred thousand annually by a single female (Leuckart), and undergo no development until they have passed out of the human body. Cleavage takes place in water, but only at the end of some months or even more than a year. The eggs are well protected by the heavy shell from adverse circumstances, so that Davaine has kept embryos living within them for five years. The introduction of these embryos still within the shell is ordinarily brought about through drinking-water, though Blanchard suggests the evident possibility of their introduction on salads and uncooked vegetables. In the human stomach the shell is dissolved and the embryos are set at liberty to reach sexual maturity at the end of a few weeks, as has been definitely established by the experiments of Grassi.

Distribution.—This is one of the commonest parasites of man, being distributed over practically the entire earth, though more abundant in the warmer regions. Local variations in its frequency are noteworthy. Braun cites, as records of autopsies, its presence at Dresden as 2.5 per cent., at Erlangen 11.1 per cent., at Kiel 31.8 per cent., at Munich 9.3 per cent., at St. Petersburg 0.18 per cent., at Göttingen 46.1 per cent., at Basel 23.7 per cent., at Greenwich 68 per cent., at Dublin 89 per cent., at Paris 50 per cent., and in Southern Italy near 100 per cent. This species is growing rarer in Paris according to statistics available, and probably elsewhere also, owing to the disuse of surface water for drinking.

Pathology. — *Trichocephalus trichiurus* inhabits the human cæcum ordinarily, but rarely also the vermiform process and colon, and may be found in persons of all ages, even occurring in infants of a year old.

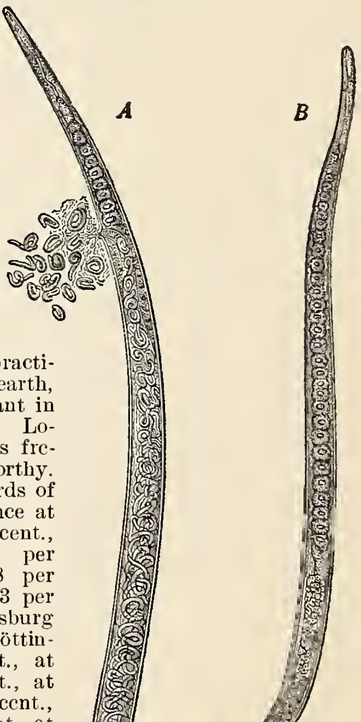

Fig. 3552.—Intestinal Trichina. *A*. Female with embryos; *B*, male, × 80. (After Heller.)

Usually only a few individuals are present in a single host, but in some cases as many as one thousand parasites have been found at once. Normally they occur with the filiform anterior region embedded in the mucosa, and recent investigation tends to demonstrate that such as are found free in the canal have been driven out by post-mortem changes.

This species has been regarded earlier as playing a pathogenic rôle in typhoid, cholera, and beri-beri, and more recently all pathogenic significance has been denied it. Though the presence of a few does not occasion pathogenic symptoms, yet since Askanazy has shown the occurrence of hæmoglobin in the alimentary canal of these worms, the fact that they nourish themselves on the blood of the host cannot be doubted. In occasional severe cases noteworthy depression, suppression of the urine, with fever, cardiac weakness, and often nervous symptoms, have been noted.

Treatment is said to be difficult, and naphthalin, thymol, and pelletierine have been used with only moderate success. A later writer commends santonin as rapid and effective.

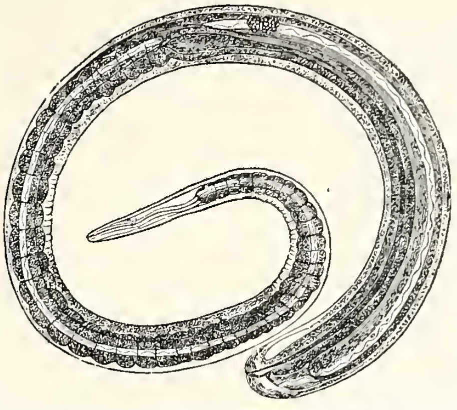
Fig. 3553.—Fully Developed Muscle Trichina with Alimentary Canal and Genital Primordium, Removed from Cyst. Magnified. (After Leuckart.)

Prophylaxis.—Care in obtaining drinking-water and in selecting and cleansing uncooked vegetables will evidently limit the spread of the parasite.

Trichinella Railliet 1896. — (Syn.: *Trichina* Owen 1835.)

Very small, slender, without marked distinction of regions in body. Male without spicule, but with lateral appendages at posterior end, as if a poorly developed bursa were present. Female ovoviviparous; vulva at anterior fifth of body. Only a single species.

Trichinella spiralis Raill. 1896.—(Syn.: *Trichina spiralis* Owen 1835.)

Male (Fig. 3552, *B*), 1.4–1.6 mm. long by 0.04 mm. broad, without spicules, but with a short conical appendage on either side of the cloaca, behind which are two pairs of papillæ. Female (Fig. 3552, *A*), 3–4 mm. long, 0.06 mm. broad; vulva ventral near anterior fifth of body; anus terminal, viviparous. Fully developed larva, 0.8–1 mm. long by 0.04 mm. broad; cyst measures 0.4 by 0.25 mm.

The sexually mature parasite, sometimes called the intestinal trichina, inhabits the small intestine of man and various other mammals. The larval form, known as the muscle trichina, is found encysted in muscular tissue. Easily infected are man, pig, rat, mouse, guinea-pig, rabbit; less easily sheep, calf, horse; with difficulty cat, dog, badger. The intestinal form will develop also in birds, but the embryos are expelled with fæces and do not reach the muscles.

History.—Encysted trichinæ were first noted by Peacock in London as early as 1828, but it was 1835 before their character as encapsulated entozoa was recognized by Paget and the parasite described by Richard Owen. The presence of encysted trichinæ in man was confirmed by a multitude of observations from various countries, and Joseph Leidy added a most important fact in the discovery of similar worms in pork. Feeding experiments by Leuckart, Virchow, and Küchenmeister, together with the observations of Zenker on a maid that had died of apparent typhoid, led to the elucidation of the life history and to proper estimation of the pathogenic character of the parasite which had heretofore been regarded as harmless or as the immature form of a *Trichocephalus* or *Strongylus*. Rapid accumulation of isolated cases and of epidemics of trichinosis, almost all from North Germany, placed beyond question the etiological significance and importance of the trichina.

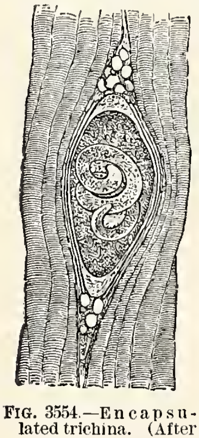
Fig. 3554.—Encapsulated trichina. (After Leuckart.)

Life History.—If a portion of flesh containing the larval worms is eaten by a suitable host, the larvæ are set free in the stomach and pass into the small intestine. They attain sexual maturity in about two and one-half days, copulate, and the male soon dies. Two opposed views as to the dispersal of the young have long been held. According to one the migration of the embryos is an active one in that they bore their own way out of the canal and through the connective tissues to their ultimate seat. The other view, however, of passive transport by the blood and lymph streams may be regarded as demonstrated by recent work, particularly that of Graham, whose account is followed in the main here. The gravid female bores into the intestinal wall as far as the lymph vessel. There the young are produced, being set free by the female into the lymph stream, which carries them ultimately into striated muscle tissue. At birth they measure 0.09–0.11 mm. in length by 5–6 μ in width, and at the close of this migration but little more, being then 0.12–0.16 mm. long. In eight days these embryos are in the intramuscular connective tissue and only a few days later in the muscle fibres themselves (Fig. 3555). The fibres lose their transverse striation and undergo granular and fatty degeneration. The embryo increases rapidly in size, and rolls into a loose spiral in an expansion of the completely degenerated fibre. By the action of the surrounding connective tissue, in which connective-tissue corpuscles and leucocytes are contained, a cyst of characteristic form is produced (Fig. 3554). It is thickened at the poles and measures about 0.4 mm. by 0.25 mm. in diameter. This process occupies several weeks, during which later broods of embryos are produced, since each female lives five to seven weeks and gives birth to from eight thousand to ten thousand young. Thus in the early stages of an infection one finds in the muscle embryos in various stages of development and encystment, side by side.

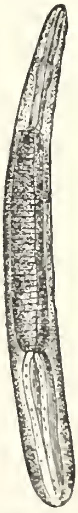
Fig. 3555.—Muscle Trichina Fifteen Days After Infection. × 165. (After Leuckart.)

Once encysted the larvæ remain quiescent; it may be for long periods. Thus encysted trichinæ have been found living in human muscle, twenty-five and even thirty-one years after the presumed infection. Not infrequently, though perhaps not always, one finds evidences of further change in the formation of a delicate calcareous layer about the cyst (Fig. 3556). In some cases this encroaches upon the larva so as to produce ultimately a calcareous nodule in which a remnant alone of the worm is contained. It is held by some that calcification does not ensue until after the death of the larva from unknown causes. Fatty degeneration of the encysted trichinæ can also be observed, and is likewise held to be a pathogenic process. Such larvæ as rarely occur in connective tissue are without the characteristic cyst, but appear to be smothered in a mass of proliferating connective tissue.

While it has been determined experimentally that a considerable number of hosts furnish conditions favorable for the development of the trichinæ, the normal host is no doubt the rat, and evidence has been adduced to prove the introduction of this parasite into Europe from the East with the brown or Norway rat. The method of transmission in this species is clear when one recalls that rats are cannibals and universally make way with aged or infirm members of the tribe. The well-known avidity with which pigs catch and eat rats explains the infection of swine, and it is from this source that man is infected.

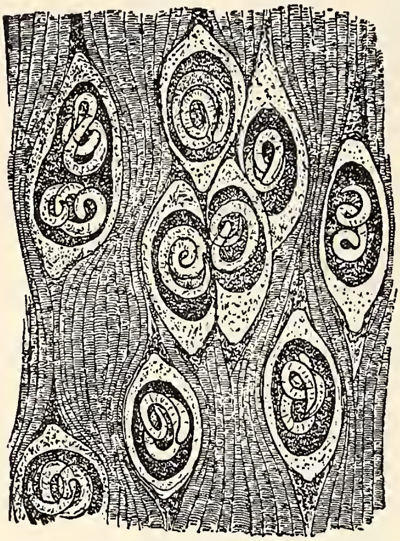

FIG. 3556.—Muscle with Encysted Trichinæ in Process of Calcification. (After Braun.)

Nearly all of the epidemics of trichinosis on record are confined to North Germany. In Saxony from 1860–75 there were 39 epidemics affecting 1,267 persons, of whom 19 died; at Hedersleben (1865), a town of about 2,000 inhabitants only, a total of 337 were sick and 101 died; at Emmersleben (1883) fully one-third died among those who ate the infected meat. Stiles has given a statistical review of trichinosis in Germany during recent years, from which is taken the following: 1860–1880—8,491 cases, 513 deaths, 6 per cent. mortality; 1881–1898—6,329 cases, 318 deaths, 5 per cent. mortality.

From the table of separate years it appears that there has been a general decrease in trichinosis in Germany during recent years, due probably to general education of the public on the dangers of eating raw pork as well as to meat inspection. The latter, which removes from consumption 1,500 to 2,000 trichinous hogs annually, is carried out in a most scientific manner by an army of some 30,000 inspectors and microscopists, at an annual cost (estimated) for the German Empire of $3,000,000, while for the city of Berlin alone the cost is $80,000. In spite of this system and expenditure security from trichinosis has not been attained *even for the meat examined*, as the following table shows, according to which more than half the cases of this disease are traceable to inspected meats.

During double the period given there have been recorded in the United States approximately 900 cases.

Of the 18 cases and 3 deaths alleged to have been due to American pork during 1881–83, neither Virchow nor others have accepted the evidence as tenable, and the careful examination made by Stiles renders it clear that the attacks upon American pork found in the German press are not supported by German health statistics. While the inspection doubtless diminishes chances of infection, it certainly gives rise to a false feeling of security.

SUMMARY FOR THE GERMAN EMPIRE 1881–98 INCLUSIVE.

	Cases.	Deaths.
Meat inspected and passed as free	2,042	112
Meat condemned but used	142	13
Due to defects in inspection system	1,204	7
Total results of errors	3,388	132
Inspection uncertain	63	0
No inspection of meat used	874	84
Data obscure or wanting	1,968	98
Said to be due to American meats	18	3
Due to uninspected Russian meat	18	1
	6,329	318

For the years 1860–95 Stiles has collected records of about 900 cases from the United States. Undoubtedly during this time cases have been diagnosed as atypical typhoid or rheumatism which were in reality attacks of trichinosis, but in the opinion of various authors there were also unrecorded cases in Germany. Nevertheless it is clear that there is a much less prevalence of the disease here, and it is interesting to note the nationality of these cases so far as recorded.

TABLE OF TWO HUNDRED AND SEVENTY-FOUR AMERICAN CASES.

	Cases.	Per cent.		Cases.	Per cent.
German	208	76.0	American	4	1.5
" Foreign "	37	13.0	French Canadian	3	1.0
Negro	10	3.0	" French descent "	1	.4
Italian	4	1.5	Dane	1	.4
Irish	4	1.5	Swede	1	.4

Statistics as to the prevalence of trichinosis are given by numerous European authorities from examinations made at autopsies. The results vary from nothing in France, according to Blanchard, to about two per cent. in Germany, according to various authors. These figures are based upon macroscopic examinations in large part at least, and Leuckart with others has remarked that greater success would follow more rigid search. In the United States Williams has subjected five hundred and five cadavers to a careful microscopical study, with the result that twenty-seven cases were found to be infected, or five and a third per cent. One-third of them were classed as severe, and only two were evident on examination with the naked eye. The nationality of the cases is given in the following table, which is suggestive, though the number is too small to warrant the drawing of final conclusions:

	Positive.	Negative.	Total.	Per cent. of positive cases in each nationality.
United States, white	6	201	207	2.89
United States, colored	5	65	70	7.14
British and Irish	5	57	62	8.06
Canadian	2	10	12	16.66
German	6	43	49	12.24
Italian	2	10	12	16.66
Other nationalities	0	27	27	0.00
Unknown	1	65	66	1.51
	27	478	505	5.34

The infection of rats varies so widely in different localities that little dependence can be placed on figures heretofore given from the examination of small numbers of individuals. The examination of pigs shows in Boston 4–5.7 per cent. infected (Billings), in United States army 2.1 per cent. (Müller), in various German districts from 1.5 per cent. to 0.1 per cent. The records of Mark show distinctly that reasonable hygienic conditions reduce the percentage of infection among pigs enormously, even in a few years.

The trichinæ are found most abundantly in the muscles of the diaphragm, tongue, and neck, and are present at times in incredible numbers, estimated by Leuckart at from thirty to forty millions for a single host (man). Diagnosis of the disease may be positively confirmed by the discovery of embryos in bits of muscle removed from the patient by scalpel or special harpoon.

The occurrence of other nematodes of somewhat similar size and appearance, the so-called false trichinæ, in the muscles and other organs of hare, rat, mouse, bird, fish, and even man (*cf.* case of Cobbold above, under *Leptodera terricola*) make it imperative that the determination be made with care in suspected cases of trichinosis. Of definite diagnostic value is the so-called "cell body" of the œsophagus, which is prominent in the anterior pointed region of the worm and which, though varying in length, is easily recognizable in all stages of growth and in both sexes (Fig. 3553).

Prophylaxis.—Man acquires the disease by the consumption of pork, in which are found living trichinæ. The chance of infection from all other animals is utterly inconsiderable, though a recent German author calls attention to the necessity of submitting dog meat to inspection on account of its rapidly increasing use as food. It has also been proved that salting, smoking, and other methods of curing ham do not afford a guarantee for the death of trichinæ which may be present. Two preventive methods have been suggested. The first is followed by Germany in her system of meat inspection; as already noted the system is expensive and does not afford absolute protection. Furthermore, unless the number of trichinæ present is enormous so that pathological changes have been induced in the flesh, the destruction of the meat constitutes an unnecessary loss of valuable food material. The second method of preventing the disease is the thorough cooking or curing of the meat so as to destroy the trichinæ. A temperature of 70° C. is sufficient to kill the encysted parasites, but in order that the centre of a piece of meat may reach this temperature cooking must be prolonged. One may determine the sufficiency of the cooking by the uniform clear gray color of a cut surface and the absence of red juice under pressure of the knife. This individual prophylaxis is both most reasonable and most effective; for the consumption of well-cooked pork is free from danger.

The old-fashioned slaughterhouse, at which the refuse was thrown to pigs and fell in part also to the rats infesting the place, was a serious menace to the health of the community, and offered the most admirable conditions for the rapid multiplication of parasites, especially these. On the other hand, the great modern packing establishments, in which all scraps are utilized under methods that destroy the life of any parasites present, are important agents in the limitation of this disease and in the general improvement of public health. Proper methods of slaughtering, curing, and preparing pork, and the abandonment of the unsanitary custom of eating the flesh of the pig uncooked are the true methods for the suppression of the disease.

Family of the Strongylidæ.—Body elongated, cylindrical, rarely filiform; alimentary canal complete; mouth provided with six papillæ, sometimes in the axis of the body, sometimes turned toward the dorsal or ventral surface, and frequently armed by chitinous teeth; œsophagus more or less enlarged at the posterior end, but not provided with a distinct bulb; sexes separate; male with caudal sac or bursa in shape like a saucer, or, if deeper, a bell encircling the end of the body. One or two spicules project from it, and the ribs or rays which mark its surface have characteristic arrangements in different species. The margin of this sac may be notched or deeply cut, so that it appears to consist of two separate parts; near the male orifice a small number of papillæ are often found. Female with one or two ovaries; female sexual opening very variable in position. The eggs when laid have undergone at least part of their development.

Strongylus apri (Gmelin 1789).—(Syn.: *Gordius pulmonalis apri* Ebel 1777; *Ascaris apri* Gmelin 1789; *Str. suis* Rud. 1809; *Str. paradoxus* Mehlis 1831: *Str. elongatus* Duj. 1845; *Str. longevaginatus* Dies. 1851; *Metastrongylus paradoxus* Molin 1860.)

Male, 12–25 mm. long, bursa bilobed, five ribs in each lobe, spicules very long and slender, measuring 2.5–4 mm. in length. Female, 20–50 mm. long, with short fish-hook tail at the base of which lies the anus and just in front of it the vulva on a rounded eminence. Eggs ellipsoid, 0.06–0.1 mm. long by 0.04–0.07 mm. broad; when laid they contain well-developed embryos.

The parasite inhabits commonly the bronchi and bronchioles of pig, sheep, and occasionally also man. Diesing reported it first from a six-year-old boy in Klausenburg; Chatin found some individuals, probably by accident, in the alimentary canal of a patient in France.

The observation of Rainey and Bristowe on nematode embryos from the larynx, which they called *Filaria trachealis*, points to this species even if an exact determination is impossible. Its abundant occurrence in the pig in Europe, and its extreme rarity in man point to some feature in the unknown life history, which renders human infection improbable.

Strongylus subtilis Looss 1895.—Body very slender and delicate, cuticula finely striated, oral papillæ inconspicuous; buccal cavity infundibuliform; œsophagus nearly one-sixth as long as the body. Male with inconspicuous alæ at anterior end, 4–5 mm. long, 90 μ in diameter at anterior end, 70 μ near bursa; two spicules, 0.15 mm. long, with accessory piece 0.05 mm. long (Fig. 3557). Bursa bilobed, with asymmetrical ribs. Female, 5.6–7 mm. long, 0.01 mm. in diameter at head, and 0.09 mm. in posterior third of body. Tail sharply pointed, anus near tip; vulva about one-fifth length from posterior end; uterus bilobed, with a few (three to six, or even eight or nine) eggs in each lobe; eggs oval, 63–70 by 41–36 μ, thin shelled, unsegmented, or partially segmented in uterus; development unknown. Infection by drinking-water.

This parasite was described by Looss from specimens found at post-mortems in Egypt. It occurred in the stomach and duodenum of man and the camel. The infection was regularly light, and Looss doubted its pathogenic character on account of this as well as its small size and unarmed buccal cavity. Later Ijima reported a record made by Ogata of the discovery of as many as two hundred small nematodes in fluid taken from the stomach of a woman who died in Japan during the "Miura plague" of 1889. These parasites were identical with Looss' species, and while they were not regarded as the cause of the epidemic, it is clear that the presence of so large a number of parasites creates a presumption against their supposed harmlessness.

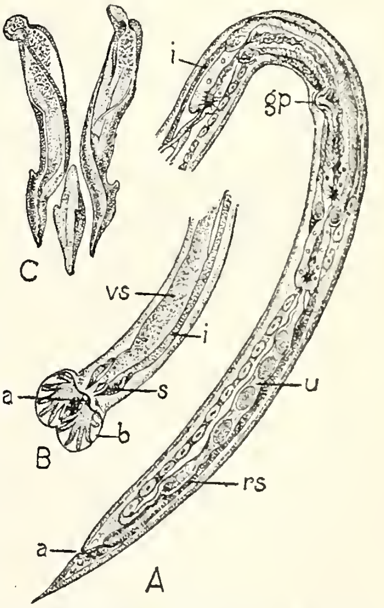

FIG. 3557.—*Strongylus subtilis.* *A*, Tail of female; *a*, anus; *gp*, genital pore; *i*, intestine; *rs*, seminal receptacle; *u*, uterus; *B*, tail of male; *b*, bursa; *s*, spicules; *vs*, seminal vesicle; *C*, spicules and accessory piece. Highly magnified. (After Looss.)

In view of its occurrence in such widely separated regions, its discovery in intermedial territory is probable, and its introduction into the United States by travellers from the Orient or by returning American troops is an evident possibility under present circumstances.

Dioctophyme renale (Goeze 1782.) — (Syn.: *Ascaris canis* et *martis* Schrank 1788; *A. visceralis* et *renalis* Gmelin 1789; *Strongylus gigas* Rud. 1802; *Eustrongylus gigas* Diesing 1851; *Strongylus renalis* Moq.-Tand. 1860; *Eu. visceralis* Raill. 1885.)

Generally blood red, slightly tapering at both ends, especially the anterior; mouth triangular, bordered by six small papillæ. Male, 13–40 cm. long, 4–6 mm. broad. Caudal extremity obtuse, encircled by membranous pouch without rib lines, but with papillæ on margin. One slender spicule, 5–6 mm. long. Female, 20 cm. to 1 meter long; 5–12 mm. broad; tail obtuse and slightly curved; anus terminal; female sexual opening, 50–70 mm. from anterior end; eggs ovoid, thick-shelled, brown, 64–68 μ by 40–43 μ.

This is the giant of all the nematoda, and is a kidney parasite encountered in man, dog, cattle, horse, wolf, and many fish-eating animals. It is extremely rare.

Life History.—The development begins in the female worm, but is completed only after the egg has been expelled from the host. Five or six months in winter and a shorter time in summer are necessary for the remainder of the development of the embryo. It lives a long time in water or moist earth, but cannot endure drying. The embryos will not develop if transferred directly to the dog, so that an intermediate host seems necessary. This has been conjectured to be a fish.

Pathology.—Of the numerous cases reported of the occurrence of this parasite in man, the majority are assignable to other parasites. Not more than ten are authentic. Trumbull's case (New York *Medical Record*, 1897) has been explained by Stiles as probably a *Filaria*.

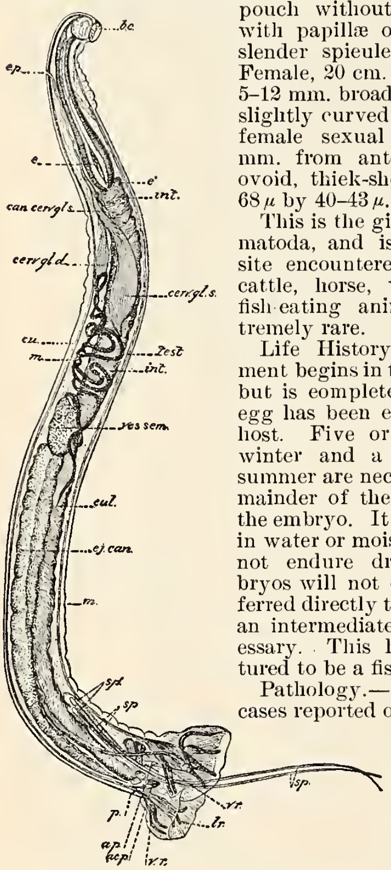

Fig. 3558.—Male of *Uncinaria duodenalis*. Magnified. (After Schulthess.)

Uncinaria Fröhlich 1789.—Anterior end curved dorsad; mouth opening obliquely from chitinous buccal capsule surrounded by transparent border; dorsal portion of capsule shorter than ventral, supported by conical structure sometimes projecting into cavity; at base of capsule two ventral teeth; near inner free border ventral wall bears on each side of the median line chitinous structures or teeth, often recurved like hooks (uncinate); inner dorsal wall also with teeth at times. Oviparous, eggs with thin transparent shell.

Of the species of this genus, which contains dangerous blood-sucking intestinal parasites of the higher mammals, two occur in man, one an Old-World species long known and the other recently discovered on this continent. In medical writings the worm is more ordinarily called *Anchylostoma*, and the disease which it produces is spoken of as anchylostomiasis. As the recent important contribution of Stiles, to whom I am also indebted for valuable personal communications, shows clearly, the name of one at least of the species in question here is that given above, and the term uncinariasis or uncinariosis should be adopted as the correct designation of the disease which is known also as brickmakers' and miners' anæmia, Egyptian chlorosis, tunnel disease, etc. Its chief symptoms are anæmia with the circulatory disturbances accompanying the pernicious type, colicky pains in the abdomen, great weakness, alternating constipation and diarrhœa with brownish or bloody stools, nausea, and œdema. Positive diagnosis is made by the discovery of the parasites and eggs in the fæces. In such cases care should be exercised not to confuse this with other species.

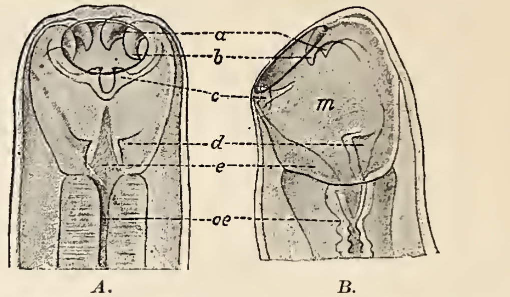

Fig. 3559.—Oral Capsule of *Uncinaria duodenalis* in (*A*) Dorsal and (*B*) Lateral Aspect. *a*, Inner; *b*, outer ventral tooth; *c*, dorsal tooth; *d*, stylet; *e*, dorsal rib; *m*, buccal cavity; *oe*, œsophagus. (After Hertwig.)

As the effects due to the two species are not distinguishable, a general discussion may be given for both together. By means of the powerful armature of the buccal capsule they pierce the intestinal mucosa and with the muscular œsophagus pump out blood. The intestinal epithelium is lost from the area taken into the capsule, and in addition to this the parasites move from spot to spot so that the host loses not only the blood taken by the parasite directly, but that lost through many minute hemorrhages at previous points of attack. The functional vitality of the intestinal wall is evidently reduced, and some are inclined to believe that the parasite also produces a poison which acts upon the host unfavorably.

Thymol and male fern are most frequently used for driving out these parasites, and Stiles quotes the following directions for thymol treatment:

Two grams of thymol at 8 A.M., repeated at 10 A.M., and castor oil or magnesia at noon. Diet of milk and soup. As some cases are obstinate, a re-examination of the fæces in a week is necessary, and the repetition of the treatment if eggs are still to be found. It should be noted that on the whole experiments are very unfavorable to the use of alcohol during the thymol treatment.

Rational prophylaxis must be based on better knowledge of the extent of the disease. When it is suspected microscopical examination of the fæces and treatment of all infected individuals are necessary preliminaries to its eradication. The construction of water-tight latrines in tunnels, brickyards, and other corporation properties where the disease is prevalent, together with the periodic disinfection of their contents by quicklime or by cremation, will largely prevent the spread of the disease. If, in addition, defecation in other places is forbidden and the regulation enforced, while on the other hand fresh pure drinking water is supplied and workmen are impressed with the necessity of personal cleanliness as a preventive for the disease,

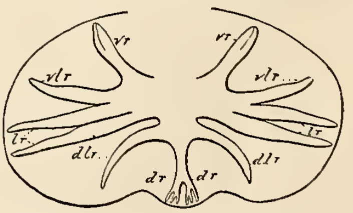

Fig. 3560.—Bursa of Male *Uncinaria duodenalis*. Magnified. (After Railliet.)

the difficulty will be reduced to a minimum. It must be kept in mind that Looss has demonstrated the probability of infection from water with larvæ coming on to the skin, so that the presence of such larvæ in standing water is a real menace, even if none of it ever reaches the mouth.

The Old-World species has been known for some time, and its effects are clearly traceable back of the historic study of Perroncito, which showed it to be the cause of the severe miners' anæmia, which was associated with the construction of the Saint Gothard tunnel. It is only within the year 1902 that Stiles has called attention to the tremendous economic and hygienic importance of the New-World species in our Southern States, although the records of the presence of some species, probably this one, extend back for many years. In Central America uncinariasis has been for centuries the most important and dangerous general disease, involving twenty-three per cent. of the population; it appears in the old Indian traditions, and with the disease is associated "dirt-eating." The species has not been precisely determined. In Africa the infected negro does not seem to be subject to any resulting anæmia.

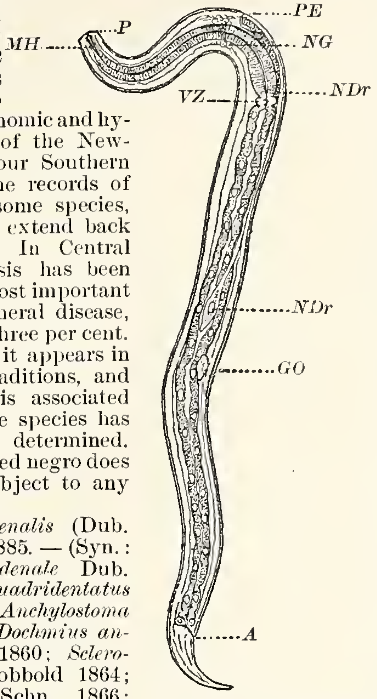

FIG. 3561.—Young *Uncinaria duodenalis* Four Days After Infection. *A*, Anus; *GO*, genital cell; *NDr*, œsophageal glands; *MH*, oral cavity. × 190. (After Looss.)

Uncinaria duodenalis (Dub. 1843) Railliet 1885. — (Syn.: *Agchylostoma duodenale* Dub. 1843; *Strongylus quadridentatus* v. Sieb. 1851; *Anchylostoma duod.* Dub. 1850; *Dochmius anchylostomum* Molin 1860; *Sclerostoma duodenale* Cobbold 1864; *Str. duodenalis* Schn. 1866; *Dochmius duodenalis* Leuck. 1876; *Ankylostoma* and *Ankylostomum duod.* auct.)

Body cylindrical; buccal cavity with two pairs of uncinate ventral teeth, and one pair of dorsal teeth, directed forward; dorsal rib not projecting into capsule. Female, 10–18 mm. long by 0.5–0.6 mm. wide; vulva at or near posterior third of body; eggs 52 by 32 μ, segmenting when deposited with direct development. Male (Fig. 3558), 8–11 mm. long by 0.4–0.5 mm. wide; caudal bursa (Fig. 3560) with dorso-medial lobe, dividing at two-thirds the distance from base, each branch being tridigitate, and with prominent lateral lobes united by a ventral lobe; spicules long, slender.

This species occurs in the upper region of the small intestine of man, and has been reported from Europe, Africa, Asia, the Philippines, and recently also from North America and the West Indies, where some regard it as of very recent introduction. A number of cases, including one fatal one, are on record in the United States within two years.

Structure.—One point in the structure deserves special attention—the so-called pharynx or buccal capsule (Fig. 3559). This is very nearly spherical, and is armed with four strong curved chitinous teeth. At the bottom of the capsule are two triangular lance-like organs, the function of which is the penetration of the tissue of the host. The body is curved dorsad at the anterior end on account of the shortness of the dorsal wall of the buccal capsule, so that the orifice actually points dorsad.

Life History.—The eggs are deposited in the alimentary canal of the host and must pass out of the body in order to undergo development, which will not take place in water, but proceeds rapidly in fæces or in slime, so that the rhabditiform embryo is hatched in twenty-four hours at 27° C. As 1° C. kills the eggs in from twenty-four to forty-eight hours, the climate of a large part of this country is an evident barrier to the spread of the parasite. At hatching the embryo measures 0.3 mm. in length, but grows rapidly, and after moulting once it enters upon a resting stage within the cast-off skin of the second moult. In this, the infecting stage of the parasite, the worms may live for a month or more in water without food, but if subjected to desiccation they perish. This naturally points to water as the probable means of infection, although the presence of such larvæ on moist salads and other vegetables, eaten uncooked, may well be a subsidiary means.

Recently Looss has brought forward the idea that these larvæ may enter the human body by way of the skin, which stands in perfect agreement with his earlier observations, that the larvæ which were fed to various animals in water did not settle down but were discharged per anum unchanged; yet part of them bored into the mucosa of the larynx and œsophagus and were active and growing two weeks later. When taken into the human body the worms undergo radical changes in structure. One may distinguish with Looss a third stage without buccal capsule (Fig. 3561), a fourth with provisional buccal capsule (Fig. 3562), and a fifth in which this organ corresponds to the adult form. From four to six weeks from the time of infection are required for the parasites to mature.

The view of Looss, that infection may take place through the skin, has been confirmed by a number of observations and experiments. Most striking was the infection of a limb about to be amputated and the subsequent discovery of many larvæ, which had forced a way in between hair and follicle and appeared in sections to have penetrated as far as the subdermal tissue. This method of infection, which Looss believes to be the most extensive, explains the susceptibility of Egyptian field laborers, and also epidemics among brickmakers as well as all cases in which the workmen are wont to work in moist earth with bare feet and hands. It explains the infection of children walking on damp ground, and gives, according to Bentley, the key to the "ground itch," or Pani-ghao, an affection of the skin of the lower extremities, endemic in Assam and in the West Indies. Its appearance is coincident with the advent of the rainy season, and is associated by this author with the presence of the larvæ of *Uncinaria duodenalis* in the soil of the infected areas. The typical lesion consists in a primary erythema followed by a vesicular eruption, which frequently becomes pustular, and in severe cases may result in obstinate ulceration or even in gangrene.

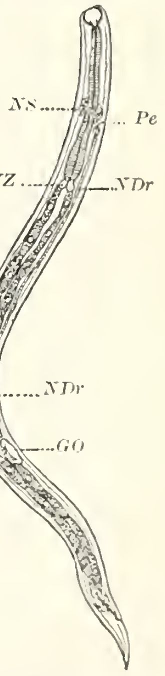

FIG. 3562.—*Uncinaria duodenalis* in Stage II. of Development. × 105 (After Looss.)

Uncinaria americana Stiles 1902.—Ventral recurved uncinate teeth absent from mouth, one pair prominent dorsal semilunar plates, and an inconspicuous ventral pair being present; dorsal median conical tooth projecting prominently into buccal capsule (Fig. 3565). Female, 9–11 mm. long by 0.31–0.35 mm. wide; vulva near middle of body but in front of it; eggs (Fig. 3564) 64–72 μ by 36–40 μ, segmenting or with well-developed embryos when deposited. Male, 7–9 mm. long by 0.29–0.31 mm. wide; dorsal ray of caudal bursa divided to the base, each branch bipartite to tip (Fig. 3563). Species otherwise similar to *U. duodenalis.*

This form has only just been differentiated by Stiles from the long known European *U. duodenalis,* from which in fact it differs radically. It has been obtained from cases of uncinariosis in man in Texas, Virginia, Florida, Porto Rico, and Cuba, and its wide occurrence goes to show that the parasite, though not recognized hitherto, is endemic in the Southern States, where it causes the most common disease on the farms and among the poor whites. The life history of the parasite is unknown, though the early stages correspond to those of *U. duodenalis.* The cases of the disease have been collected and abstracted by Stiles, who holds with evident right that it is not a recently imported disease, but has existed unrecognized for years. It has been traced from Virginia to Florida, and is most abundant in sandy areas. Guiteras has also an unpublished case from Brazil.

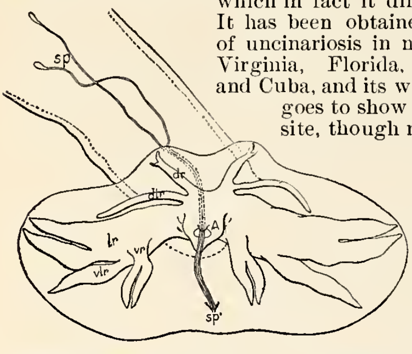

FIG. 3563.—Bursa of *Uncinaria americana*, Showing Ribs (*dr*, *lr*, etc.). *a*, Anus; *sp*, spicules. Magnified. (After Stiles.)

Physaloptera caucasica von Linstow 1902.—Cuticula heavy, non-striated, forming a projecting ring about the head, within which a pair of equilateral lips bear four papillæ in the submedian line and two conical teeth near the mouth opening. Œsophagus one-fifth the entire length; lateral lines strongly developed. Male, 14.22 mm. long by 0.71 mm. broad; bursa broad, rounded, tapering posteriad, with central longitudinal rows of small conical papillæ; spicules two unlike; lateral to the cloacal orifice two pairs of long stalked papillæ, in front one pair, behind two pairs, on the tail three pairs more. Female, 27 mm. long, 1.14 mm. broad, vulva at one-sixth the length from the anterior end; eggs heavy shelled, 57 by 39 μ.

The single account of this species by O. von Linstow is based on specimens, two males and nine females, in the collection of the museum at St. Petersburg, Russia. They are said to have been taken from the alimentary canal of man in the Caucasus. Further details are not given.

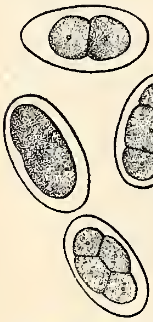
FIG. 3564.—Eggs of *Uncinaria americana* from Fæces. × 235. (After Stiles.)

Family of the Ascaridæ.—Body relatively thick; mouth surrounded by three lips, one of which is dorsal, the others ventrolateral; œsophagus long, muscular, inflated at the end and often accompanied by an œsophageal bulb; male with one or two spicules; female with double ovary, oviparous; development direct. All are intestinal parasites.

Ascaris L. 1758.—Polymyaria, with very prominent lips; males with two equal spicules and many preanal and postanal papillæ; vulva in advance of centre of body. More than two hundred species are recorded; three have been reported from man.

Ascaris lumbricoides L. 1758.—Body reddish or grayish-yellow when living; spindle-shaped; lips (Fig. 3566) almost similar, approximately semicircular, with fine teeth on the edges, the dorsal possesses two papillæ, and each of the ventral ones only a single papilla. Male, 15–17 or even 25 cm. long and 3 mm. thick, with the posterior end curved toward the ventral face; spicules two, short, 2 mm. long; papillæ fifty-five to sixty preanal and seven pairs postanal. The female, 20–25 or even 40 cm. long and 5–5.5 mm. thick, with straight conical posterior end. The female sexual opening at the limit of the anterior third of the body, and situated in a ring-shaped depression. Fertilized eggs (Fig. 3567) elliptical, shell with transparent mammillated covering, 50–75 μ long by 40–58 μ wide, laid before cleavage begins. Unfertilized eggs, irregular, with scanty albumin covering, coarser granules, and thinner shell, measuring 81 by 45 μ.

This, the common round worm of children, is one of the most abundant and widely distributed of human parasites. It is distributed over the entire world, and though more abundant in the warmer regions, is recorded from Finland and Greenland. It is also more common in the country than in cities, which may be due to the presence of the same species in the pig and sheep. This parasite was well known to the ancients, both the Greeks and the Romans, although the ἀσκαρις of Greek authors is the form now known as *Oxyuris.*

Life History.—The development of the eggs does not begin until long after they have been expelled from the human intestine, and is dependent upon both moisture and warmth. Under mean temperature the embryo is completed in from thirty to forty days, and then lies in a spiral within a thin shell, which it does not seem to leave so long as the egg remains free, though it undergoes a moult here. The embryo may live long within the shell, even up to five years. The further development was believed by Leuckart to require the intervention of another host in which a larval stage is passed, but Davaine was successful in hatching the embryos in the intestine of the rat, and believes that the intervention of a second host is unnecessary. Subsequent experiments by various authors have strongly confirmed this view by raising experimentally adults in the human alimentary canal two months after the ingestion of eggs containing embryos. Accordingly the eggs are probably introduced into the human system with the embryo within by accident or by means of the drinking-water. The embryo is then set at liberty in the alimentary canal, and further development is merely growth. Of course the infection may be brought about by the means of contaminated vegetables, especially salads, which have been imperfectly cleaned.

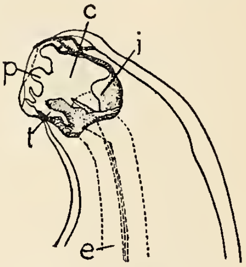

FIG. 3565.—Lateral View of Head of *Uncinaria americana.* *c*, Oral capsule; *e*, œsophagus; *i*, stylet; *p*, papilla; *t*, dorsal median tooth. (After Stiles.)

Pathology.—It has already been mentioned that the worms are most frequently found in children of medium growth, but this is due to the ease of infection rather than to conditions for development, since the worm has been obtained from persons of all ages. Ordinarily one finds only a few specimens at once, but in some cases from five hundred to one thousand have been obtained from a single individual. It is noteworthy that hæmoglobin has been detected in the alimentary canal of the

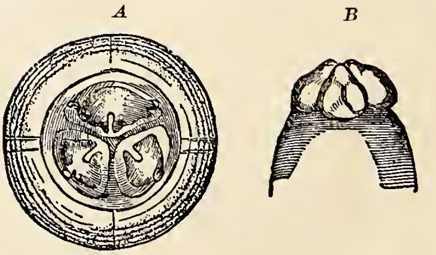

FIG. 3566.—Anterior End of *Ascaris lumbricoides.* *A*, Apical and *B*, Dorsal Aspect.

parasite, showing that its food consists in part of human blood. Their normal location is the small intestine, but specimens not infrequently wander into the stomach and are vomited. Rarely they have been known to make their way into the pharynx and choanæ, with the result of causing fatal suffocation both in children and in adults; also into the Eustachian tube or ductus choledochus, and they have even been found in abscesses of the liver.

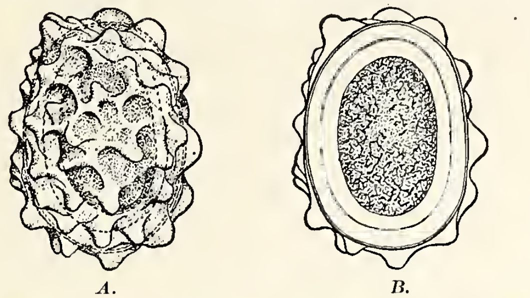

FIG. 3567.—Egg of *Ascaris lumbricoides* from Fæces. *A*, In surface view and *B* in optical section. (After Stiles.)

Recently a number of unimpeachable cases have been brought forward in which the worm has bored its way through the uninjured wall of the intestine and has been found in the peritoneal cavity. Their presence here after having pierced abscesses of the wall is also known, and in some cases even, in which adhesion of the intestinal to the abdominal wall was present, the worm emerged from the body through an abscess at this point. In fevers the Ascaridæ will spontaneously desert the intestine.

It is evident that these wanderings are associated with great danger to the host. The presence also even of a few individuals in the intestine gives rise at times to marked nervous disturbances, hysteria, epileptic attacks, congestion of the brain, aphonia, etc., which are most easily explained on the basis of a poison excreted by the worms. In fact, recent investigators have been able to obtain such a toxic substance from the body of this species, and students in the laboratory handling specimens of *A. megalocephala* from the horse have been distinctly affected by poisonous emanations. The symptoms disappear with the removal of the worms. Moniez, however, is inclined to attribute the troubles in large part to the use of santonin for the expulsion of the worms, as this substance has an unfavorable effect upon the human organism. Guiart has called attention to the important fact that the parasites by their movements produce lesions of the wall so as to afford a point of attack for intestinal fevers, and thus become a source of great danger for the host. Knotted masses of this parasite have also been the cause of fatal intestinal obstruction.

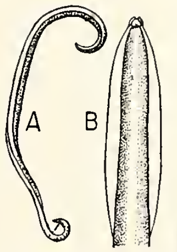

FIG. 3568.—*Ascaris canis*. *A*, Male. (Natural size.) *B*, Head showing papillæ and wings. Magnified. (Original.)

Treatment.—In general opinion santonin is the specific against *Ascaris*, and no one of the many other substances tried has achieved the same results. Moniez advises the use of centigrams equal to the number of years in a child's age, and for an adult 20–25 cgm. The drug kills the parasites, and the administration at the same time of a purgative is advantageous in bringing about their immediate expulsion. Careful watch should be kept for the violent symptoms which sometimes accompany the use of santonin and means taken at once to counteract them.

Ascaris canis Blanchard.—(Syn.: *Lumbricus canis* Werner 1782; *A. teres* Goeze 1782; *A. cati* and *caniculæ* Schrank 1788; *A. canis* and *felis* Gmelin 1789; *A. tricuspidata* and *felis* Bruguière 1791; *A. Werneri* Rud. 1793; *Fusaria mystax* Zeder 1800; *A. marginata* and *A. mystax* Rud. 1802; *A. alata* Bellingham 1839.) Anterior end ordinarily curved and provided with two wing-like membranes which extend one along each side (Fig. 3568), lips almost equal, three to six-cornered. Male, 40–90 mm. long, 1 mm. broad, with twenty-one preanal and five postanal papillæ. Female, 120–200 mm. long, vulva in the anterior fourth of the body, eggs almost spherical with thin shell, 0.068–0.072 mm. in diameter.

An abundant parasite in the small intestine of cats and dogs and also reported from various allied wild species, it has been found several times in man in England, Germany, Denmark, and the United States. Grassi doubts the accuracy of these determinations since experimental infection was not successful.

The development is direct and in general like that of the preceding species. The thin shell is highly impervious so that development continues in alcohol, turpentine, etc. It is probable that the embryo does not desert the shell until taken into the stomach of the host.

Ascaris maritima Leuckart 1876.—Known only from a single immature female, which was vomited by a child in North Greenland in 1865. The specimen was 43 mm. long and 1 mm. broad, and is regarded by some authors not as a normal parasite, but as one accidentally ingested with the viscera of some food animal. According to Leuckart it is very near *A. transfuga* of the bears.

Oxyuris Rudolphi 1803.—Three lips poorly developed or wanting; œsophagus long and provided with a distinct bulb. Male with only one spicule and with two pairs of preanal papillæ. Female with greatly elongated, pointed posterior end, two ovaries and vulva in anterior part of the body.

Oxyuris vermicularis Bremser 1819.—(Syn.: *Ascaris vermicularis* L. 1767; *Fusaria vermicularis* Zeder 1803. Œsophagus long and followed by a distinct bulb with teeth; body white, cuticula striated, forming wing-like projections from the dorsal and ventral surfaces near the head and also a low crest along the lateral lines of the body; three small retractile labial papillæ. Male, 3–5 mm. long, with spirally rolled tail; a single spicule and six pairs of papillæ. Female, 9–12 mm. long, 1 mm. broad, tail awl-shaped; vulva a little in front of the limit of the anterior fourth of the body; eggs elliptical, thin-shelled, 50–54 μ long by 20–27 μ wide, containing an embryo when deposited (Fig. 3569).

This species, known from remote antiquity, is a cosmopolitan parasite of the human intestine. It has not been definitely recognized as a parasite of other animals, but Leidey's *O. compar* from the cat is very likely the same form. It is more abundant in cities than in the country, and occurs equally in cold and warm regions. These parasites are most abundant in infants, a fact which accords with the ease of auto-infection as shown by the development.

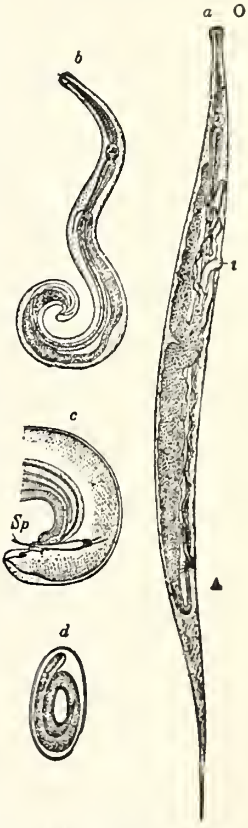

FIG. 3569.—*Oxyuris vermicularis*. *a*, Female; *b*, male; *c*, posterior end of latter; *d*, egg with embryo; *i*, vulva; *sp*, spicule. Magnified. (After Leuckart.)

Life History.—The embryo develops within the egg shell while still contained in the uterus, and it was long thought that the further development could take place in the canal. In fact, however, the female at the time of oviposition lives in the lower part of the rectum and even attains the vicinity of the anus, although the earlier portion of the adult life history is passed in the small intestine, where the worms acquire sexual maturity and copulate. Evacuated from the body, the embryo undergoes transformation to the second embryonic stage while still within the egg shell, and now awaits ingestion by a new host. The primary infection is by drinking-water or contaminated fruit or vegetables, which are eaten uncooked; but self-infection and transference to other individuals are brought about by scratching and rubbing with the fingers to allay the intense itching caused by the daily migration of the females out from the anus on to the perineum and the surrounding parts. Perhaps in the distribution of *Oxyuris* eggs the flies play a part such as Grassi has demonstrated for *Trichocephalus* and eggs of *Tænia.* The direct development is very rapid, as Leuckart obtained experimentally *Oxyurides* 6–7 mm. long within fourteen days after ingestion of the eggs; Grassi and others have confirmed this by further experiments.

Pathology.—The females are far more numerous than the males, and by their migrations determine unbearable pruritus, which recurs periodically on retiring. In a number of cases among young girls the worms have migrated into the vagina and have produced onanism, and even the inception of nymphomania. In many cases large numbers in the rectum have excited no untoward symptoms, but in others they have produced reflex nervous activities of all grades up to epileptic attacks, such as have been noted under *Ascaris.* Recent investigations in Egypt have demonstrated the responsibility of this parasite for nodules on the rectal wall, previously attributed to *Schistosoma,* which contain eggs of *Oxyuris vermicularis* in a calculus. *Oxyuris* has also been recorded in tuberculous nodules in the cavum Douglasii of a female, and Vuillemin has recently discovered them in a tumor near the anus of a boy. The latter case shows definitely the wandering of the worms through 2 cm. or more of solid tissue. This habit exhibits a new and evidently dangerous feature in the parasitism of this species through the disturbance of the tissues and the introduction into them of bacteria from the rectum.

Treatment.—It is difficult to remove these worms entirely. Vermifuges and purgatives with enemata, etc., are successful to a degree; but the ease of auto-infection is an obstacle to a complete cure. Local application of mercurial ointment will alleviate the pruritus, and manual extraction, if prolonged, will reduce their numbers rapidly. But in any event treatment is prolonged.

The sub-class of the Gordiacea includes forms familiarly known as "hair snakes" or "hair worms." They are greatly elongated, slender worms, somewhat filaria-like in external appearance, but of radically different internal structure. Lateral fields are wanting, and the body musculation is of a different histological type from that of the Eunematoda. The mouth is occluded and the alimentary canal persists in the adult only as a functionless vestigial strand. In both sexes the reproductive organs open to the exterior with the alimentary canal at a terminal or subterminal cloaca. The reproductive system is constructed on a different plan, and the lateral canal system is wanting. The male has no spicules, but the posterior end of the body is forked and functions as grasping organ.

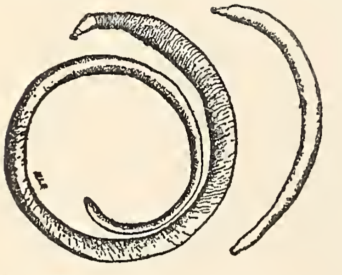

FIG. 3570. — *Gigantorhynchus gigas.* Male at right, female at left. Half natural size. (Original.)

The adult lives free in ponds, swamps, and other bodies of water, and the eggs are deposited on the stems of water plants. The larvæ possess a proboscis armed with hooks and bore into the body cavity of aquicolous insect larvæ, or rarely mollusks, where they encyst. According to Villot the second stage is passed in the intestine and body cavity of fishes. More commonly apparently the worms develop to maturity in the body cavity of insects, from which they emerge into the water for the adult free existence.

Several species have been reported from the human alimentary canal. They are pseudoparasites, having been swallowed, according to one view, in the adult condition with drinking-water; but their occurrence in fruit, especially apples, makes this even a more likely source of infection. Lockwood noted in 1876 the frequent presence, in fruit, of *Mermis,* another genus of Eunematoda, and suggested the probable occurrence of this form as a pseudoparasite of man under conditions; this has not been actually recorded so far as I find. But of Gordius as a pseudoparasite Parona has recently listed eleven cases, the first as early as 1638; of these Kirtland's (Ohio) is the only one from the United States. Two other unpublished cases have recently been communicated to me from Michigan and Maryland. It will be of no particular value to enter here upon a detailed description of the species found.

The Gordiacea are, however, emphasized by Cobbold as important for the medical practitioner, since they have been passed off as the guinea-worm and as having been evacuated with fecal matter by neurasthenic persons under treatment.

The Acanthocephala may best be discussed as an appendix to the class Nematoda, although they are regarded by many as a cognate class and by others are separated even more widely. The forms included here, though parasites of the most complete type, are not common in man. The group may be characterized as follows: Elongated, cylindrical body, often deeply corrugated, bearing at anterior end a retractile proboscis provided with many minute hooks in rows. No trace of alimentary canal. Reproductive organs open at posterior end; sexes separate. Male with campanulate bursa about the orifice. Mostly small forms, parasitic as adults in vertebrates only. The structure is uniform, and can be learned from the brief account which follows of the largest and commonest species.

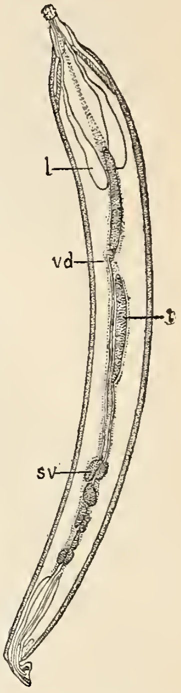

FIG. 3571.—*Gigantorhynchus gigas* Opened to Show Internal Anatomy, *l,* Lemniscus; *sv,* seminal vesicle; *t,* testis; *vd,* vas deferens. Modified. (Original.)

Gigantorhynchus gigas Hamann 1892.—(Syn.: *Tænia hirudinacea* Pallas 1781; *Echinorhynchus gigas* Goeze 1782.)

Body milk white, sometimes slightly tinted, with transverse irregular ridges. Posterior end somewhat smaller; proboscis spherical, armed with five or six rows of hooks. The proboscis can be retracted into a neck-like region, which is much slimmer than the following portion of the body. Male, 60–90 mm. long by 3–5 mm. broad, with bell-shaped caudal pouch. Female, 230–350 mm. long by 4–9 mm. broad; tail blunt; eggs almost cylindrical, 0.087–0.1 mm. long with three embryonic envelopes.

The adult worm is found in the small intestine of the pig, ordinarily fixed to the wall by the proboscis, and is widely distributed.

Structure.—The elongated body (Fig. 3570) is largest near the head and tapers gradually toward the posterior end. At the anterior end a sharp constriction separates the body from the short neck portion, which is not more than one-fourth or one-fifth the diameter of the body close to it. From the apex of this region may be projected the proboscis which is contained within it, like the reversed finger of a glove. As the proboscis rolls out the hooks also turn outward, and when the proboscis is completely extruded the shape of the organ is nearly that of a sphere on which are from five to six irregular rows of hooks. Behind these the proboscis is slightly smaller.

If the internal structure be examined, it will be seen that the proboscis is provided with retractor muscles, by means of which it may be withdrawn into the body. At the base of the proboscis is the small mass of nervous matter which represents the brain.

There is no trace of an alimentary canal, hence these forms, like the tapeworm, take nourishment by absorption. Two elongated sac-like organs hang down into the body cavity along the sides of the proboscis. These are the lemnisci (*l*, Fig. 3571); their function is uncertain.

The mass of the body is made up of the organs of the reproductive system. All these worms are diœcious. The male organs (Fig. 3571) consist of two large testes, together with the ducts and accessory glands connected with them. The tail of the male has a hemispherical expansion, something like the caudal bursa of other Nematoda; the male sexual opening in the centre of this sac at the tip of the body is provided with a small copulatory organ. The internal sexual organs of the female are much similar in general appearance; the ovaries lie toward the front of the body cavity, which is largely filled with eggs in various stages of development. These are discharged by the oviduct, which opens at the posterior end of the body.

Life History.—The eggs of *Gigantorynchus* are discharged from the alimentary canal of the host and distributed with fæces. When eaten by some insect they are hatched in its intestine. The embryo, which has a conical form armed at one end with four hooks like tapeworm hooks, and a number of smaller ones, penetrates into the abdominal cavity of the insect and encysts there. In this condition the embryos may even live through the metamorphoses of the insect until the host is eaten by some pig. In the alimentary canal of the pig the embryo is set free, attaches itself and acquires maturity. There is some dispute as to what insect is the intermediate host; the white worm-like larva of the May bug and the larva of the common rose chafer have been found to contain these worms in Europe, and Stiles has experimentally infected the larvæ of the June bug in this country. It is also maintained that various species of snail may function as the larval host. In all probability the larva is not confined to a single host, but may develop in many.

Leuckart accepts some reports of the occurrence of this species in man as trustworthy, and Lindemann says that it is not rare as a human parasite in Southern Russia. Schneider notes the consumption, as food, of the larvæ and adults of *Melalontha*, the May beetle, which acts as the intermediate host, so that infection is evidently possible.

Gigantorhynchus moniliformis (Bremser 1819).—Body attenuated anteriorly. Proboscis, 0.425–0.450 mm. long, 0.175–0.19 mm. broad, with hooks in fifteen transverse and twelve longitudinal rows. Male, 4-4.5 cm. long. Female, 7–8 cm. long, or even up to 27 cm., according to Westrumb. Eggs ellipsoidal, 85 μ long, 45 μ broad.

The normal hosts of this species are field mice, rats, etc., and the intermediate host in Italy has been determined as *Blaps mucronata*. Calandruccio in experimenting on the life history succeeded in infecting himself with the adult. The severe symptoms which manifested themselves were dispelled by the evacuation of the worms. In other cases of the occurrence of this species as a human parasite its identity was less definitely established.

Echinorhynchus hominis Lambl 1859.—Length, 5.6 mm.; width, 0.6 mm.; proboscis almost spherical with twelve transverse rows of eight hooks each. Large hooks, 103 μ long, small hooks, 77 μ.

An uncertain species of which Lambl found a single specimen at Prague in the small intestine of a boy who had died of leukæmia.

Echinorhynchus sp. Welch 1872.—In 1872 Welch described as *Echinorhynchus* a body which he found encysted in the mucosa of the jejunum of a soldier. According to Railliet it was evidently a Linguatulid (see *Arachnida*).

Echinorhynchus sp. Moniez 1896.—Kunstler and Pitres found certain peculiar bodies in the pleural cavity of a patient who had suffered two years from pleurisy, but without fever. They interpreted these structures as coccidia, but Moniez holds with greater probability to their likeness to eggs of *Echinorhynchus*. The case is entirely isolated under either explanation.

Henry B. Ward.

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NEOPLASMS. See *Tumors.*

NEPHRECTOMY; NEPHROTOMY. See *Kidneys, etc.*

NERVES, GENERAL PHYSIOLOGY OF.—Histological and General.—Nerves consist essentially of the long, slender processes of nerve cells. They are hence composed of protoplasm, and they possess the general chemical and physical properties of this substance; but they differ physiologically from other forms of protoplasm, in that they possess to a high degree the properties of conductivity and excitability, while the properties of growth, metabolism, respiration, and contractility are feebly developed or altogether absent. There is in these respects a marked physiological difference even between the nerve and the cell body from which it arises. Many of the reactions of the cells to external conditions are the opposite to the reactions of the nerve. The cell generates nerve impulses; it possesses spontaneity or automatism, absent in the fibre; it is closely dependent on a supply of oxygen, while the nerve is almost independent; it has an active metabolism, which the nerve lacks almost entirely; it respires, while the nerve respires little or not at all; it or some of its dendritic processes may be contractile, the nerve has lost this property altogether. The physiology of the nervous tissue, which includes nerve cells, differs therefore in many respects from that of the nerves proper, which we shall consider here. In short, the nerve cells possess pre-eminently the property of automatism or spontaneity; the nerve fibre, the property of conduction.

This physiological differentiation of the conducting protoplasm of the nerve is accompanied, as might be expected, by an histological differentiation. The protoplasm of the nerve fibre, called the axis cylinder, or axon, differs in physical appearance from that of the rest of the cell body from which it is derived, in that the fibre is striated longitudinally as if composed of distinct fibrils, and is surrounded by a fatty sheath. These fibrils can be more easily seen in invertebrate than in vertebrate nerves, and particularly in the leeches, where they have been traced by Apathy[1] from one nerve cell into and even through other nerve cells. Some observers even go so far as to maintain that these fibrils are the true conducting portions of the fibre, but of this there is no physiological evidence. Besides this peculiar fibrillar structure of the axis cylinder, nerves are as a rule easily differentiated from other tissues even by the naked eye by their white, glistening, fatty sheaths. Nearly all nerve fibres which take their origin in the brain and spinal cord, and many having origin elsewhere, are surrounded by such a sheath, which is called the medulla, and such nerves are called medullated nerves. The nerves of invertebrates and those of the sympathetic system of vertebrates, on the other hand, often lack these sheaths, and are called non-medullated nerves. The function of this medullated sheath is not definitely ascertained, but it has been suggested that it prevents the spreading of the impulse from one fibre to another. It appears to influence the physiological behavior of the nerve, for medullated nerves are generally more easily excited than non-medullated, and they react differently to an exposure to a constant electrical current. A momentary exposure of a non-medullated nerve to a constant electrical current may block conduction in the region of the anode or positive electrode for several minutes or hours; whereas medullated nerves after such treatment recover their conductivity very quickly.[38] Waller[2] suggested that the medulla was reserve material which was used up by the metabolism of the nerve during conduction, and he explained in this way the indefatigability which medullated nerves possess; but Miss Sowton[3] has recently shown that the non-medullated olfactory nerve of fishes is almost or quite as inexhaustible as are medullated nerves, if we may judge from the undiminished size of the electrical response attending conduction after long stimulation. Nerve fibres differ from other protoplasm also in the quickness with which they stain blue when exposed to a solution of methylene blue. It is thus possible to stain them before the other tissues are colored, and an important method for tracing the course and distribution of nerves has been founded on this peculiarity.

The chemical composition of the axis-cylinder process is not definitely known. Other portions of gray nervous matter which it resembles consist largely of colloidal substances of proteid nature, and differ from most tissues in the unusually large amounts of lecithin and cholesterin present. Nothing can be said positively regarding the inorganic salts present in the axis-cylinder process. Ranke[4] believed its reaction to be slightly acid, but most observers have found the cut surface of the nerve alkaline to litmus; it is possible that like other protoplasm it is neutral to phenolphthalein. The medulla consists chiefly of cerebrin, lecithin, cephalin, cholesterin, and neurokeratin. The latter substance forms a horny supporting framework. Lecithin is a trimethyl cholin-distearyl phosphoric acid glycerin ester. Other fatty acids may be present in place of the stearic acid, and the lecithins from different animals vary in this respect. The kephalin or cephalin, according to Koch and Thudicum, is probably monomethyl cholin lecithin. The constitution of cerebrin is unknown, but in the brain of the sheep it contains the sugar galactose, two or four molecules of stearic or oleic acid containing nitrogen, possibly united to a hexatomic alcohol or to glycerin. The cerebrins obtained from the brains of different animals differ chemically. The high content of all nerve tissues in lecithin and cholesterin is probably of physiological importance, as will be shown farther on, and possibly determines their susceptibility to the anæsthetics.

As the conducting part of a nerve fibre consists of protoplasm, it cannot continue to exist for any length of time if cut off from the rest of the cell, but soon degenerates and disintegrates. Experiments on plant cells and infusoria have shown that portions of the cell cut away from the nucleus die and no longer grow, although they may continue movement and some other functions for some days.[5] The nerve fibre shows the same relationship, demonstrating that its maintenance in a normal condition depends on its connection with a nucleated part of the cell body. If a mammalian nerve is severed, the peripheral portion, whether sensory or motor, loses its power of conduction and excitability in from four to six days.[9] In frogs conduction may persist for from five to eight days, and, in nerves kept cool, even longer. These facts indicate that the nerve fibre, however close its connection with the peripheral cell which it innervates, is not nourished from it and does not enter into organic connection with it; and, further, that it is not nourished by the nuclei of the medullary sheath. No immediate functional reunion of the peripheral and the central ends of a severed nerve can be brought about by suturing, for whether sutured or not degeneration of the peripheral part always occurs. This is accompanied by the division of the nuclei of the medulla and the fragmentation and fatty degeneration of the axis cylinder and medullary sheath. Degeneration does not extend gradually downward from the cut end of the fibre, but takes place with the same rapidity in the whole of the cut-off portion. The restoral of function in the cut nerve is brought about by the growth downward of the central ends of the cut fibres—of those fibres, in other words, still in connection with the nerve cells.[6] These push down in the paths of the degenerating fibres and ultimately become medullated and re-establish union with the peripheral organs, although this may be prevented if the fibres meet in their course any obstacle which turns them aside. There appears to be no choice of termination on the part of the fibre—for example, of a motor fibre for a muscle cell or of a sensory fibre for a sensory end-organ—for if the central end of a sensory nerve is sutured to the peripheral end of a cut motor nerve, the sensory fibres will innervate the muscle fibres formerly supplied by the motor nerve, and vice versa.[7] Also if the vagus and sympathetic be cut and the central end of the vagus cross-sutured with the upper end of the sympathetic in the neck, the vagus fibres growing upward in the paths of the degenerating sympathetic innervate the submaxillary gland and cause secretion on stimulation, and thus take on a secretory function.[8] Similar facts have been established by Langley for the fibres innervating the pupil and those erecting the hairs on the cat's neck, and by Cunningham and other observers in other nerves. The time required for the restoration of the function of the nerve will depend in part on the distance the nerve has to grow to re-establish union, and in part on the nerve which is regenerating. The longer the distance which the regenerating fibre has to grow before reaching its destination, the longer will be the time required for regeneration. On the other hand, nerves differ somewhat in their speed of regeneration or growth, and no doubt constitutional differences of this sort exist among different individuals. The time required is as a rule from two weeks to four or more months. For some reason the nerve fibres within the cord appear in mammals to have little power of regeneration if the cord is severed. The reason for this peculiar reaction is not yet satisfactorily explained. The subject is badly in need of careful investigation, since even the possibility of regeneration in mammals is not definitely disproved.[10]

Excitability.—Nerves are excitable—that is, they will respond to stimulation, at any point in the course of the fibre. No variation in excitability at different points of the nerve has been detected in any one nerve as long as it remains uninjured in the body,[11] but if the nerve is injured by cutting it or its branches, an increase of ex-

Parasites.

The paraplegiform affection due to the ataxia of tabes dorsalis may give place to a true paraplegia by an extension of the degenerative process to the anterior cornua, producing muscular atrophy, or, in the form combined with sclerosis, by involving the pyramidal tracts, it may develop spastic and ataxic paraplegia.

SPASTIC PARAPLEGIA results, as we have seen, from the symmetrical involvement of the pyramidal tracts in any part of their course, and is usually secondary to a transverse myelitis, or to a transverse lesion of the pyramidal tracts in their intracranial portion, or, particularly in infants, to arrested development of the cortical motor areas, in both hemispheres. It is sometimes termed double hemiplegia. It may affect chiefly the arms, or the legs, and has the usual characteristics, namely, spastic movements, exaggerated reflexes, and absence of sensory and trophic changes. Primary sclerosis of the pyramidal tracts in the cord is a rare condition, if it occurs at all.

Intracranial tumors, by pressure upon the crura and pyramidal tracts in the pons and medulla, or in the cerebellum, may produce paraplegia or paraplegiform symptoms, in some cases being ataxic rather than paretic, or a combination of both.

PARAPLEGIA FROM MULTIPLE NEURITIS is characterized by both motor and sensory impairment involving all the extremities, and ascending the members from periphery to trunk, also by pain, hyperæsthesia, tenderness of the nerve trunks to pressure, trophic changes in the muscles, the reaction of degeneration, œdema of the extremities, the absence of visceral disturbances (bladder and rectum), and the absence of a constriction band. It is most common in those addicted to alcohol, but is also a manifestation of certain endemic diseases, such as beriberi or kakki.

PSEUDO-HYPERTROPHIC PARALYSIS produces a form of paraplegia somewhat similar to poliomyelitis anterior, and is considered by some to be a form of that affection, by others to be a connective-tissue disease of the muscles. The increase in size of the muscle (usually the calves) and its hardness, serve to distinguish it from ordinary poliomyelitis anterior.

There are several forms of paraplegia usually classified under functional disorders of the nervous system, namely, hysterical paraplegia, paraplegia depending upon idea, reflex paraplegia, malarial paraplegia, anæmic paraplegia, alcoholic paraplegia, and toxic paraplegia.

HYSTERICAL PARAPLEGIA is a less frequent form of hysterical paralysis than that of hemiplegic or monoplegic distribution. It is less apt to be confounded with paralysis of organic origin than the other varieties, for the reason that hysterical paralysis resembles in its symptoms a lesion of cerebral motor tracts in the brain and cord, rather than one in the remaining portion of the motor tract in the cord and peripheral nerves. The reaction of degeneration is absent in hysterical paralysis. Atrophy may be present, but it is that form which is dependent upon disuse. The volume of the muscles may be reduced in such cases, and may give a feeble reaction to electrical excitation; but, what is of the utmost importance, *faradic excitability is preserved, and the contractions are quick.* The skin and muscles may be cold, livid, and flabby, resembling paralysis from peripheral or cornual disease, and contractures may form as in degeneration of the pyramidal tracts, though in many cases the muscles and skin appear normal, except that voluntary control is lost. The tendon reflexes are rarely lost; usually they are increased, sometimes excessively so. The bladder and rectum are not usually affected, though voluntary control over these organs may be lost. Thus, paraplegia from transverse myelitis of the lumbar enlargement would not be confounded with hysterical paraplegia on account of the absence in the latter of trophic and electrical changes in the muscles and nerves, bedsores, and atrophic changes in the bladder; but the latter might closely resemble paraplegia from transverse dorsal myelitis in which these signs are absent. The presence of a constriction band at the level of the segment involved, and the sensory, motor, or reflex disturbances in this zone would exclude hysterical paraplegia. Hysterical paralysis of all the extremities might simulate cervical paraplegia of myelitic origin, but would be differentiated from it by the presence of trophic changes in the muscles of the upper extremities, and by the vaso-motor and visceral symptoms which accompany organic lesions of this region. Again, the onset and course of the two classes of disease are usually sufficient to distinguish one from the other. The irritative stage of most acute or subacute organic diseases of the cord, in which pain, hyperæsthesia, and slight motor irritation precede the paretic and anæsthetic period, is not usually present in hysterical paraplegia. In the latter, sudden development of the paraplegia, and sudden variations in its distribution and intensity, often serve to indicate it. Anæsthesia and analgesia may have a distribution inconsistent with the lesions producing paraplegia of structural origin.

It must not be forgotten that hysteria may accompany organic lesions, and should not, therefore, be taken as proof of the hysterical nature of the paralysis, unless organic lesions can be excluded.

PARAPLEGIA DEPENDENT UPON IDEA is a form described by Dr. J. Russell Reynolds. Though closely allied to hysterical paralysis, it may be independent of hysteria, hypochondriasis, and simulation, though frequently associated with functional debility, anxiety, and a morbid imagination. "Many cases of paraplegia following railroad accidents," says Reynolds, "may be classed under this head; the attention of the victim being influenced in the most unfortunate manner by the stories of friends, inquiries of his physician, the talk of his attorney, and the sober face of the company's physician." Pain, distributed in a manner inconsistent with the anatomical relations, on the supposition of an organic lesion; spasm, which, however, is sometimes relaxed in a remarkable way when the patient's attention is directed elsewhere; and paralysis, which is rarely complete, and almost identical with a voluntary attempt not to move the parts, or to move them with care, as in simulation, are the chief features of the affection. The removal of the morbid idea, *i.e.*, that the patient is paralyzed, or has a severe disease, results in improvement or cure. An award for damages has also frequently proven a valuable therapeutic agent in such cases.

REFLEX PARAPLEGIA, termed by older writers urinary paraplegia, was shown by Brown-Séquard to follow irritation not only of the genito-urinary tract, but also of the intestines and other viscera in animals. He attributed it to an anæmia of the cord, due to contraction of the blood-vessels, while Charcot considered the motor weakness due to inhibitory action of the sensory irritation. While we must admit the possibility of this form of paraplegia, it should not be forgotten that organic lesions may have been lost sight of, or might be sufficiently slight to be transitory. The positive evidence of some form of peripheral irritation, the removal of which has been followed by recovery, is the only basis on which it should be admitted, and then only in the absence of indications of organic disease.

MALARIAL OR INTERMITTENT PARAPLEGIA is a curious form of poliomyelitis anterior, which recurs with the periodicity of intermittent fever. Alcoholic paraplegia, when not due to multiple neuritis, is a temporary affair, following an alcoholic debauch.

ANÆMIC PARAPLEGIA follows ischæmia of the cord, from pressure on the abdominal aorta, and from pressure or occlusion of the iliac arteries within the pelvis, or ischæmia of muscles; rare conditions.

The indications for *treatment*, where paraplegia exists, are those adapted to the correction of the various pathological processes concerned in the diseases which we have considered. More than a brief résumé would carry us beyond the proper limits of this work. In the irritative stage of acute meningitic and myelitic processes, rest is the first essential. The reduction of hyperæmia, by means of agents supposed to cause vaso-motor contraction, such as ergot and belladonna, and the relief of pain by means of cutaneous irritation (the actual cautery, blisters, sinapisms, cupping, etc.), and also by morphine, may be attempted. The use of cold to reduce inflammation in spinal-cord disease is an uncertain procedure, concerning the real effects of which we know but little.

In the destructive stage of these conditions, when paralytic and anæsthetic phenomena are present, rest may still be an important factor. The use of mercury, and of potassium iodide, may be of service in this period to promote the absorption of exudations.

In later stages and in chronic cases the use of tonics, of iron, strychnine, arsenic, etc., is called for. Nitrate of silver may be indicated. Electricity is usually to be avoided in the irritative stage of an acute affection; or, if used, as for the relief of pain, it should be in the form of a gradually increased galvanic current, avoiding interruption. For the paralysis, the interrupted galvanic and the faradic currents, to produce muscular contractions, and spinal applications of the uninterrupted galvanic current, are of value, as are also massage and passive movements. For anæsthesia, the faradic brush is often serviceable.

Extreme care and cleanliness are essential in all cases of paraplegia, and the avoidance of pressure and irritation over the buttocks and sacrum, on account of the danger and frequency of bedsores. Attention must be paid to the bladder and rectum. Catheterization, conducted with extreme cleanliness, may be necessary, and also antiseptic irrigation of the bladder. Constipation must be prevented by cathartics, enemas, etc. Compression myelitis from caries, dislocations, fractures, and other traumatisms requires appropriate surgical treatment.

W. R. Birdsall.

PARASITES.—A parasite is an organism which lives, temporarily or permanently, within the body or on the surface of some other living thing upon which it feeds. Evidently, then, not only may there be both phytoparasites and zoöparasites, but also that form which is parasitized upon and is known as the host may be equally either plant or animal. Among forms which find in man at some time or in some region a subject for attack, the phytoparasites include the prominent group of bacteria which have received attention elsewhere, and a few fungi of etiological importance, in dermal affections chiefly, which have also been discussed. Here will be given a brief discussion of the animal parasites of man, with especial reference to their biological and etiological relations.

It is important to notice first the wide range in degree of parasitism exhibited and the manner in which the various grades merge into one another, producing a scale of dependence in which almost every stage is represented. Most independent of all are the temporary parasites, like the mosquito, bedbug, or leech, which stay by the individual host only long enough to secure a single meal, and which present clearly the structure and habits of free living organisms. Some leeches suggest most plainly the close relation between the carnivorous and the parasitic habit since they often devour bodily small aquatic forms, but when favored by opportunity extract the blood of larger animals. More dependent are such forms as the fleas which can change their host and often do so, and yet their structure has been highly modified in the loss of wings which are generally characteristic of insects and by the development of powerful leaping and grasping organs. Somewhat further modified in the direction of parasitism are the lice, which, moreover, lack special means for effecting a change of host, and may be included among the list of stationary parasites—*i.e.*, those that remain with a single host constantly, or at least for considerable periods of time.

All of the forms thus far noted are parasitic upon the exterior of the host, and consequently are denominated Epizoa or ectoparasites. All human ectoparasites belong to the group of Arthropoda, and include both mites (*cf. Arachnida*) and true insects (*cf. Insects*). Among the water-living animals, however, soft-bodied forms, such as flat worms (Trematoda) and unicellular animals (Protozoa) occur as Epizoa. With the gradual assumption of an aërial or terrestrial existence on the part of the host such parasites were necessitated, if they had not already sought more sheltered regions, now at least to abandon the external surface and to colonize internal organs where thin mucous membranes afforded facilities for extracting nourishment similar to those which existed on the thin outer skin of the aquicolous animal. The choanæ, pharynx, gills, lungs, alimentary canal, and even the bladder were thus invaded by forms whose kinship to the ectoparasitic species on these lower animals is too plain to fail of recognition.

The Entozoa or endoparasites of man, however, do not even belong to the same branch of the animal kingdom as the forms ectoparasitic upon him, with the single exception of the rare and aberrant Linguatulids, now usually regarded as highly degenerate arachnids (*q.v.*), though formerly classed with the Cestoda. The human Entozoa include Protozoa, Trematoda, Cestoda, and Nematoda, and many of them are highly modified in adaptation to the parasitic mode of existence, as compared to the related free living forms which, however, are entirely wanting in the second and third groups listed.

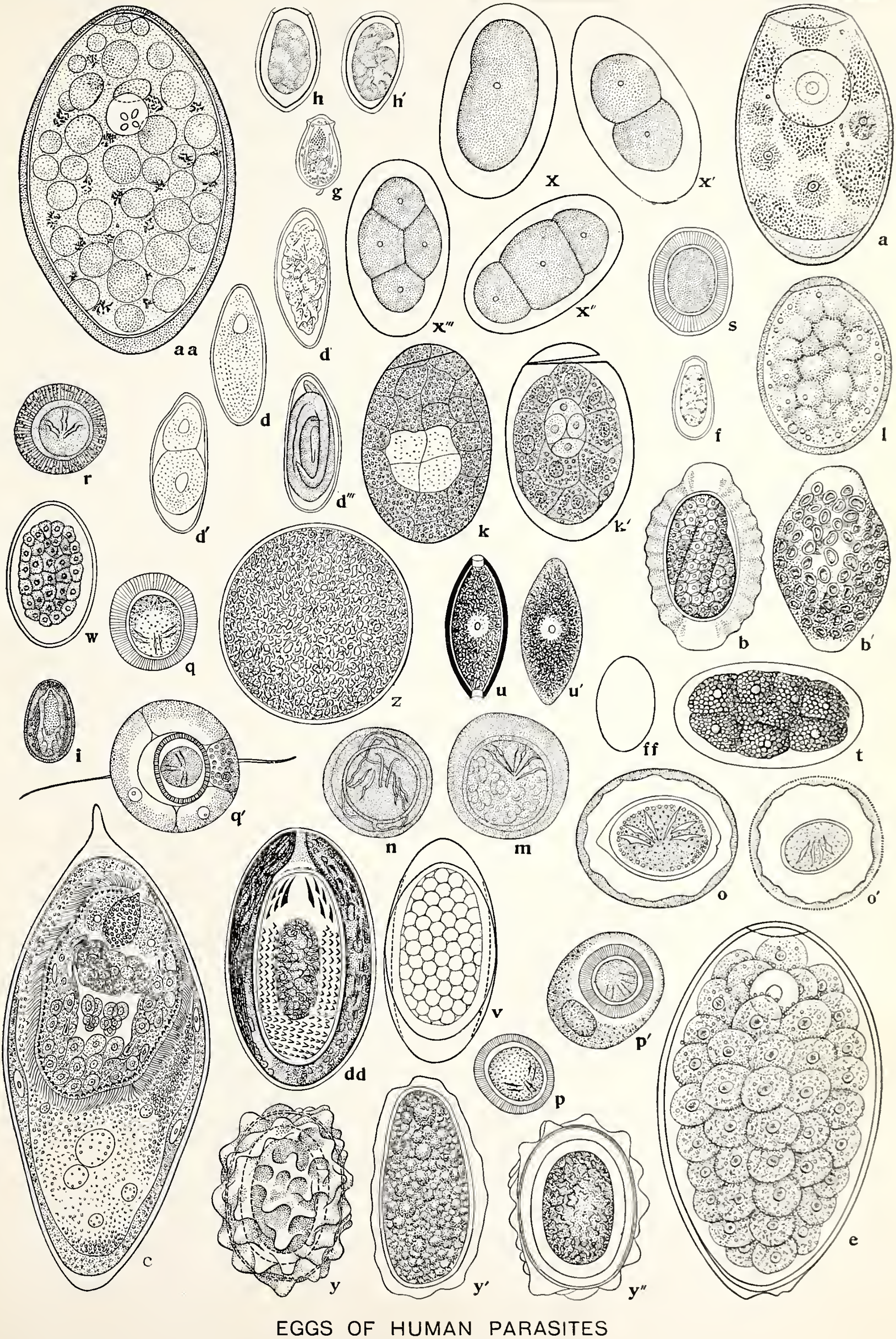
The term helminthology has been used as synonymous with animal parasitology, and yet this is a considerable extension of its original meaning. The Helminthes or intestinal worms included the pre-eminently parasitic groups, such as Trematoda, Cestoda, and Nematoda, while the Protozoa, Arthropoda, and even the few parasitic Terbellaria, which are in fact closely related to Trematoda, were omitted. The term became thus one of convenience rather than of scientific accuracy.

It is necessary to emphasize the fact that neither Helminthes nor parasites constitute a group of systematic value. At most the forms are related in a biologic sense and not structurally, for they are comprehended in several distinct branches of the animal kingdom, and a given form is often more closely related to free living species than to other parasitic forms. Even the narrower term Helminthes embraced forms of little similarity to each other and rightly to be distributed with their related free living species into several distinct groups, namely, the Linguatulida to the Arachnida, the Trematoda and Cestoda to the Plathelminthes, and the Nematoda to the Nemathelminthes.

Location.—While the majority of endoparasites inhabit the alimentary canal and its adnexa, there is no organ which is immune to them. The following list of human parasites arranged according to the organ inhabited will serve to indicate the extent of the parasitic habit, and will assist in the identification of a given form. The records given apply only to the human host. Parasites are entered under the normal location of the species, and in the most frequent erratic location only; a few forms of doubtful standing, as human parasites or of uncertain location in this host, are omitted.

Parasite.	Stage.	Type of parasitism.	Normal habitat.	Recorded in U.S.A.
Skin and subdermal tissue.				
Leptodera Niellyi	Larva	Accidental.	Europe	No.
Gnathostoma siamense	Adult	Occasional.	Siam	No.
Filaria medinensis	Adult	Normal	Africa	Yes.
Uncinaria duodenale	Larva	(?)	Cosmopolitan.	Yes.
Eye.				
Filaria loa	Adult	Normal	Africa	Yes.
Filaria lentis	Adult	(?)	(?)	No.
Filaria conjunctivæ	Adult	Occasional.	Europe	No.
Cysticercus cellulosæ	Larva	Erratic	Europe	No.
Echinococcus polymorphus.	Larva	Erratic	Europe	Yes.
Brain and membranes.				
Cysticercus racemosus=cellulosæ.	Larva	Erratic	Europe	Yes.
Cysticercus acanthotrias.	Larva	Erratic (?).	U. S. A	Yes.
Echinococcus polymorphus.	Larva	Erratic	Europe	Yes.

PLATE E.



EGGS OF HUMAN PARASITES

(MAGNIFIED FIVE HUNDRED DIAMETERS)

Parasite.	Stage.	Type of parasitism.	Normal habitat.	Recorded in U. S. A.
Brain and membranes.				
Paragonimus Westermanni.	Adult..	Erratic	Asia.......	*
Connective tissue.				
Fasciola hepatica........	Adult..	Erratic	Europe	*
Bothriocephalus Mansoni	Larva ..	Occasional.	China	No.
Cysticercus cellulosæ....	Larva ..	Normal....	Europe	Yes.
Cysticercus acanthotrias..	Larva ..	Normal....	U. S. A	Yes.
Echinococcus polymorphus.	Larva ..	Normal....	Europe	Yes.
Filaria loa...............	Adult..	Normal....	Africa	Yes.
Paragonimus Westermanni.	Adult..	Erratic	Asia.......	*
Muscles.				
Cysticercus cellulosæ....	Larva ..	Normal....	Europe	No.
Cysticercus acanthotrias..	Larva ..	Normal....	U. S. A	Yes.
Trichinella spiralis	Larva ..	Normal....	Cosmopolitan.	Yes.
Heart.				
Filaria Magalhaesi.......	Adult..	(?).........	So. Amer..	No.
Cysticercus cellulosæ....	Larva ..	Erratic	Europe....	No.
Echinococcus polymorphus.	Larva ..	Erratic	Europe	Yes.
Blood-vessels.				
Fasciola hepatica........	Adult..	Erratic	Europe	*
Schistosoma hæmatobium.	Adult..	Normal....	Africa	Yes.
Echinoccus polymorphus.	Larva ..	Normal....	Europe	Yes.
Filaria immitis (?).......	Adult..	Occasional.	Europe	*
Filaria embryos (see key under Nematoda).	....	Normal....	....	Yes.
Lymph vessels.				
Filaria Bancrofti	Adult..	Normal....	Tropics....	Yes.
Filaria volvulus..........	Adult..	Normal....	Africa	No.
Filaria lymphatica.......	Adult..	Occasional.	Europe	No.
Lungs.				
Fasciola angusta.........	Adult..	Erratic	Africa......	No.
Paragonimus Westermanni.	Adult..	Normal....	Asia.......	*
Cysticercus cellulosæ....	Larva ..	Normal....	Europe	No.
Echinococcus polymorphus.	Larva ..	Normal....	Europe	Yes.
Strongylus apri	Adult..	Occasional.	Europe....	No.
Liver.				
Fasciola hepatica	Adult..	Occasional.	Europe	*
Opisthorchis felineus	Adult..	Normal....	Russia	No.
Opisthorchis sinensis	Adult..	Normal....	Asia.......	Yes.
Opisthorchis noverca	Adult..	Normal....	Asia.......	No.
Distoma Rathouisi.......	Adult..	Occasional?	Asia.......	No.
Dicrocœlium lanceatum.	Adult..	Normal....	Europe	*
Cysticercus cellulosæ	Larva ..	Normal....	Europe	No.
Echinococcus polymorphus.	Larva ..	Normal....	Europe	Yes.
Paragonimus Westermanni.	Adult..	Erratic	Asia.......	*
Small intestines.				
Fasciolopsis Buski.......	Adult..	Normal....	Asia.......	No.
Opisthorchis felineus	Adult..	Erratic	Russia.....	No.
Opisthorchis sinensis	Adult..	Erratic	Asia.......	No.
Heterophyes heterophyes	Adult..	Normal....	Africa	No.
Dibothriocephalus latus..	Adult..	Normal....	Europe	Yes.
Dibothriocephalus cordatus.	Adult..	Occasional.	Greenland.	No.
Diplogonoporus grandis .	Adult..	Occasional.	Japan	No.
Dipylidium caninum.....	Adult..	Occasional.	Europe	Yes.
Hymenolepis nana.......	Adult..	Normal (?).	Europe	Yes.
Hymenolepis diminuta ..	Adult..	Occasional.	Europe	Yes.
Hymenolepis lanceolata .	Adult..	Occasional.	Europe	No.
Davainea madagascarensis.	Adult..	Occasional (?).	Africa	No.
Tænia solium	Adult..	Normal....	Cosmopolitan.	Yes.
Tænia saginata..........	Adult..	Normal....	Cosmopolitan.	Yes.
Tænia africana..........	Adult..	Normal....	Africa	No.
Tænia confusa	Adult..	Normal (?).	U. S. A	Yes.
Strongyloides stercoralis.	Adult..	Normal....	Asia.......	Yes.
Trichinella spiralis	Adult..	Normal....	Cosmopolitan.	Yes.
Strongylus subtilis.......	Adult..	Normal....	Africa.....	No.
Uncinaria duodenalis ...	Adult..	Normal....	Cosmopolitan.	Yes.
Uncinaria americana	Adult..	Normal....	America ..	Yes.
Physaloptera caucasica..	Adult..	(?).........	Caucasus...	No.
Ascaris lumbricoides	Adult..	Normal....	Cosmopolitan.	Yes.
Ascaris canis	Adult..	Occasional.	Europe	*
Ascaris maritima........	Adult..	Occasional.	Greenland.	No.
Oxyuris vermicularis	Adult..	Normal....	Cosmopolitan.	Yes.
Gigantorhyuchus gigas..	Adult..	Occasional.	Cosmopolitan.	No.
Gigantorhynchus moniliformis.	Adult..	Occasional.	Cosmopolitan.	No.
Large intestine.				
Gastrodiscus hominis....	Adult..	Occasional (?).	India......	Yes.
Trichocephalus trichiurus	Adult..	Normal....	Cosmopolitan.	No.
Oxyuris vermicularis	Female.	Normal....	Cosmopolitan.	Yes.
Kidney.				
Echinococcus polymorphus.	Larva ..	Normal....	Europe	Yes.
Dioctophyme renale.....	Adult..	Occasional.	Europe	*
Bladder.				
Leptodera pellio	Adult..	Accidental.	Europe	No.
Anguillula aceti.........	Adult..	Accidental.	U. S. A	Yes.

SPUTUM—EGGS.

Parasite.	Frequence.	Size in microns.	Plate E.
Fasciola angusta	Recorded once.	143–151 × 82–88.	
Fasciola hepatica........	Not observed, but possible.	Given below under Fæces.	
Fasciola magna, etc.....			
Paragonimus Westermanni.	Frequent	88–103 × 53–68.	Fig. *a*.
Strongylus apri	Few cases	50–100 × 39–72.	

SPUTUM—EMBRYOS.

Filaria, many species possible (see key under *Nematoda*).

URINE—EGGS.

Parasite.	Frequence.	Size in microns.	Plate E.
Fasciola hepatica.......	Not observed, but possible.	Given below under Fæces.	
Fasciola magna, etc.....			
Schistosoma hæmatobium	Frequent	135–160 × 55–66.	Fig. *c*.
Filaria Bancrofti.........	Recorded once.	25–28 × 15 (or 35 ?).	
Dioctophyme renale......	Few cases	64–68 × 40–49.	Fig. *b*, *b'*.
Oxyuris vermicularis†....	Common	50–54 × 20–27.	Fig. *d*, *d'*, *d''*, *d'''*.

URINE—EMBRYOS.

Filaria, many species possible (see key under *Nematoda*).

The eggs of the other kidney parasites will not hatch as long as kept in urine.

Adult forms, like accidental parasites of the Nematode type, are so small as to be easily taken for embryos (see Anguillula aceti, etc., under *Nematoda*).

FÆCES—EGGS.

Parasite.	Frequence.	Size in microns.	Plate E.
Gastrodiscus hominis	Recorded once.	150 × 72.	
Fasciola hepatica.........	Several cases ..	130–172 × 72–80.	Fig. *e*.
Fasciola magna	Not recorded ..	109–168 × 75–96.	Fig. *aa*.
Fasciola angusta	Recorded once.	143–151 × 82–88.	
Distoma Rathouisi	Recorded once.	150 × 80.	
Fasciolopsis Buski........	Several cases ..	120–126 × 77.	
Opisthorchis felineus.....	Several cases ..	26–30 × 11–15.	Fig. *f*.
Opisthorchis noverca	Recorded once.	34 × 21.	Fig. *ff*.
Opisthorchis sinensis	Several cases ..	27–30 × 15–17.	Fig. *g*.
Dicrocœlium lanceatum..	Several cases ..	40–45 × 22–30.	Figs. *h*, *h'*.
Heterophyes heterophyes.	Frequent	26–30 × 15–17.	Fig. *i*.
Paragonimus Westermanni.	Frequent	88–103 × 53–68.	Fig. *a*.
Dibothriocephalus latus..	Frequent	68–71 × 45	Figs. *k*, *k'*.
Dibothriocephalus cordatus.	Reported once.	75–80 × 50.	
Diplogonoporus grandis ..	Few cases	63 × 48–50.	Fig. *l*.
Dipylidium caninum	Few cases	43–50, embryo 32–36.	Fig. *m*.
Hymenolepis nana	Frequent	39, or 43 × 31.	Fig. *n*.
Hymenolepis diminuta ..,	Several cases ..	70–86, embryo 36 × 28.	Figs. *o*, *o'*.
Hymenolepis lanceolata..	Recorded once.	50 × 35.	
Tænia solium	Frequent	30–35, embryo 20	Figs. *p*, *p'*.
Tænia saginata	Common	(Yolk membrane 70) 30–40 × 20–33.	Figs. *q*, *q'*.
Tænia africana	Recorded once.	31–34 round, or 31 × 39.	Fig. *r*.
Tænia confusa	Two cases	30 × 39.	Fig. *s*.
Strongyloides stercoralis..	Frequent	67 × 37.	Fig. *t*.
Trichocephalus trichiurus.	Common	50–54 × 21–23.	Figs. *u*, *u'*.

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* Present in the United States of America in some other host, hence easily possible in man, although no record of its occurrence in the human host was found.

* Present in the United States of America in some other host, hence easily possible in man, although no record of its occurrence in the human host was found.

† Only in female through infection of vagina from rectum.

FÆCES—EGGS.—*Continued.*

Parasite.	Frequence.	Size in microns.	Plate E.
Strongylus subtilis	Several cases ..	63–80 × 35–41.	Fig. *v*.
Strongylus apri	Few cases	50–100 × 39–72.	
Uncinaria duodenalis	Frequent	55–65 × 32–45.	Fig. *w*.
Uncinaria americana.....	Frequent	64–72 × 36–40.	Figs. x, x', x'', x'''.
Physaloptera caucasica...	Reported once.	57 × 39.	
Ascaris lumbricoides	Common	50–75 × 40–50, fertilized.	Fig. y y''.
		63–98 × 31–77 unfertilized.	Fig. y'.
Ascaris canis..............	Few cases	72–68, spherical.	Fig. *z*.
Oxyuris vermicularis.....	Common.	50 × 16–20.	Figs. d, d', d'', d'''.
Gigantorhynchus gigas...	Few cases.	80–100 long, oval	Fig. *dd*.
Gigantorhynchus moniliformis.	Few cases.	85 × 40.	

FÆCES—EMBRYOS.

Parasite.	Frequence.	Size in microns.	Plate.
Filaria.*			
Strongyloides stercoralis..	Common	200–400 long.	
Trichinella spiralis	Rare	90–100 × 6.	

* Many species possible (see key under *Nematoda*).

One may recognize among these parasites those which occur in their normal host but in an unusual location, like the brain cysticerci or a liver fluke in a subcutaneous cyst; there are also many of the species listed which cannot be regarded in any way as characteristic of the human host. Such are the occasional parasites which are species of true parasitic habit and can attain normal development in the human host, but ordinarily do not find conditions favorable for their introduction. As an instance of such species may be mentioned *Fasciola hepatica*, the common liver fluke of the sheep, which in many regions of the world is extraordinarily abundant. That it can thrive in the human system is demonstrated by the score or more of cases of its occurrence there definitely recorded; but its infrequence is equal evidence of a general immunity on the part of man, lacking in these particular cases, or of special features in its life history which make the infection of the human host difficult. That the latter is the probable explanation may be inferred from the fact that the cercaria larva, liberated from the intermediate host, encysts on grass, and hence could reach the human alimentary canal only under unusual circumstances. Similar examples may be taken from other groups of parasitic forms, such as the rare occurrence in man of *Strongylus apri*, one of the commonest parasites of the pig in Europe, or of *Dipylidium caninum*, the cosmopolitan tapeworm of both dog and cat, which has been reported only rarely from man.

Such occasional parasites often occur under abnormal conditions; thus a fish nematode, *Ascaris clavata*, was discovered once in the hollow tooth of a man. Here the position was probably accidental, but in other cases it is the result of the action of the parasite itself. So the "red spiders," or "jigger" mites of the Central States bury themselves in the skin of man, although such a position is so clearly abnormal that in fact it destroys the chance of further development and costs the parasite its life. A small leech, *Limnotis nilotica*, common in the Circummediterranean area, is often drawn into the throat of men and other animals drinking at wayside pools. It usually retains its position, causing serious difficulty, until removed by operative interference; hence it has become an occasional parasite of man rather than, as in the case of most leeches, a temporary parasite; or one may regard it as falling in the next following group of accidental parasites. This example shows most clearly the narrow and somewhat artificial limits which separate these groups of parasites from one another. Of the mites also, which have been reported a few times as obtained living from stomach, bladder, and rectum, it is difficult to say whether they are occasional or accidental parasites of man.

There are also rarely forms which commonly occur free living, but which by chance are introduced into some organ in which conditions are such that they can thrive. They become thus accidental parasites, a group difficult practically to distinguish from the last, the occasional parasites, and yet presenting somewhat different biological conditions. The recent discovery by Stiles and Frankland, as well as others, of the vinegar eel, *Anguillula aceti*, as an apparently successful colonizer of the bladder in a female patient illustrates the type under consideration. There is little doubt that this parasite was introduced through the use of vinegar in vaginal douches and effected a successful colonization, possibly by virtue of the trace of albumin present in the urine which furnished it with nourishment. Equally striking is the case of Scheiber, who discovered *Leptodera pellio* in the urine of a female patient in Hungary. This typical slime-inhabiting nematode gained entrance, no doubt, through the application of mud poultices, which are commonly employed by peasants in that region. It should be noticed that such accidental parasites are necessarily confined to those groups of animals which have free-living forms. Such are Protozoa, Nematoda, and perhaps Insecta in the larval condition, while Cestoda and Trematoda, which live only as parasitic forms in some host, would become rather occasional parasites of man should they stray into the human system in some chance manner and find favorable conditions for existence.

Quite distinct from the types just considered are pseudo-parasites, which rank high in clinical importance. Among them one may recognize several very distinct classes. First, those which are actually free-living animals, introduced by accident, usually in food or drink, into the human alimentary canal, exciting there abnormal conditions which induce their more or less immediate and forcible expulsion. Thus Botkin found in the vomit of a Russian numbers of a small nematode which he wrongly believed to be a human parasite. In fact it lives normally in the onion, and its introduction into the stomach with this food excited the untoward symptoms noted. Similarly Blanchard records a case in which coleopterous larvæ were found in the vomit of a child.

That such may be the result of introducing a true parasite from some other host is indicated by several cases, like that of *Ascaris maritima*, which Leuckart described from a single specimen vomited by a child in Greenland, and which this author noted was very similar to *A. transfuga* of the brown bear. In all probability it was ingested with the viscera of some animal (seal?), though it may have been a species which had strayed into this unusual host, only to make its appearance under the circumstances noted.

Of similar import are the cases of *Gordius*, the hair snake, which have been reported from man. In the adult condition this is normally a free-living species, but about a dozen specimens have been taken from man after a supposed sojourn of from a few hours to fourteen days. Some of these have been vomited and others passed per anum. This form has often been passed off upon the physician as a true parasite, and in one celebrated case at least as the Guinea-worm.

In the same way one may find the explanation for other isolated cases of parasitism, even when the parasite is reported to have been passed from the alimentary canal. Thus Cobbold reported that larvæ of *Blaps mortisaga*, the English churchyard beetle, were found in fecal discharges, and many authors have recorded the presence of dipterous larvæ in the alimentary canal.

The majority of such observers have inclined to regard these larvæ as temporary endoparasites, and to consider that they have accommodated themselves to the conditions present in the human host. The cases seem to show that these larvæ live for some time in the canal, and they often appear to evoke serious or even fatal disturbances; and yet the conclusions are open to grave doubt, for Calandruccio experimented extensively on two families of flies to which many of the supposed accidental parasites belong, and found that the ingested larvæ were regularly and promptly evacuated, dead or dying, and in no case did they secure a footing in the canal.

Among the myriapods about forty recorded cases of pseudoparasitism have been brought together and discussed by Blanchard. In the large majority the animal was taken from the nasal fossæ, though in a smaller number it was actually obtained living from the alimentary canal, where it undoubtedly can exist for a brief time in spite of the untoward environment. The ingestion of such forms is purely accidental, the symptoms are those of helminthiasis in general, and their stay at most is very limited. They never show any evidence of adaptation to the new environment.

In some such accidental fashion other forms are sometimes introduced into various organs not connected with the alimentary system. Thus Trouessart reported the occurrence of a species of detricolous Sarcoptids in the human testicle where the mites formed an old colony in a painless cystic tumor.

In contrast with the living animals of the types noted, the second class of pseudoparasites includes a large number of other structures which have been described as parasites. These may be considered conveniently in a few groups, the first of which includes bodies which are parts of the so-called host animal itself. Thus fragments of the arteria hyaloidea have been described as eye worms (*Filaria lentis, F. oculi humani*, etc.), the organisms of whooping-cough are nothing more nor less than ciliated tracheal cells torn from the wall and found in the sputum in distorted form, while groups of small axillary and inguinal glands, hydatid moles, and Pacchionian bodies from the arachnoid have been frequently put on record as hydatid cysts.

Parts of substances used as food, both of plant and of animal origin, which have not been destroyed by the action of digestive juices are also among the pseudoparasites of man. The radulæ of the common limpet have been reported several times from stools; the seeds of the mulberry were duly baptized as parasitic worms; and plant vessels and other similar undigested structures of peculiar appearance appear periodically as new helminthes. That a differentiation of such structures is not simple appears from the account given by Stiles of the partially digested banana fibres which closely simulate minute tapeworms. Some years ago Leuckart entrapped a group of research students in helminthology with the pulp vesicles of an orange which were found in a fecal examination.

In all of the cases considered above it should be kept in mind that the animals or these other structures actually came from within the human body. There is, however, another class of objects of which this cannot be said.

In determining the nature of unusual forms reported from man it should always be kept in mind that in the absence of positive personal evidence, suspicion in case of neurasthenia at least favors the deceitful introduction of doubtful bodies. In many cases on record such things as earthworms, chicken entrails, etc., have been forcibly introduced into the rectum or vagina, and have been subsequently reported by the attending physician as undoubted human entozoa of a remarkable character! Here as elsewhere the appearance of unusual structures should at once arouse the suspicion of the physician and call forth a most searching examination of the case in all its factors, that any deceit be disclosed, or that in the event of the discovery of some rare parasite all conditions connected with its appearance be put on record for future use. The large number of parasites in other animals which some unusual combination of circumstances may bring into the human system makes it imperative also that any supposedly new species be submitted to the judgment of a specialist before it is described as such. Only in this way can the discoverer avoid adding to the long list of synonyms, which already burden the literature of this subject, and render it so difficult for the investigator not a specialist in this particular line to find his way aright. Furthermore, it is important to preserve the fullest data in regard to any substances associated with the supposed parasite, as well as the food of the patient, whether usual or unusual, since in this way some hint as to its introduction may be found.

Effect upon the Host.—In the belief of the medical profession two hundred years ago there was no disease, real or imaginary, which was not due to the presence and effect of some kind of parasite. Each ailment had its particular "worm" in its characteristic location. This was a direct result of the endeavor to reduce every malady to some definite cause, and of the joining of the unknown sickness with the parasites of which they knew as little. Under the influence of study and of increasing knowledge regarding the parasites such a theory was seen to be untenable, and the movement in the opposite direction began, a tendency which may be said by this time to have passed its height.

It is true that internal parasites are very widely distributed, and that scarcely any individual is entirely free from them. They are, however, usually present in limited numbers, and are believed to be harmless if infrequent or of small size. This does not seem to be strictly correct, for while it is doubtless true that the effect of a single parasite, or even of a considerable number of minute size, is small and difficult to measure or estimate, it is equally clear that even this is a certain drain on the host. Furthermore, the tax on the host is in proportion not only to the number and size, but also to the habits of the parasites present. Thus there is a great difference whether the parasite is active and growing in the alimentary canal or some other cavity in the body of the host, or passively resting in the midst of the tissue of some organ.

While encysted parasites exercise a continued and sometimes serious pressure on adjacent tissue, yet the draft on the host by free parasites is much the greatest, and manifests itself in three ways. The parasite requires a certain amount of food for its support; this it takes directly from the host, either from that which the latter has digested for its own use, if the parasite be in the alimentary canal, or from material which the host has formed to perform certain work, as in the case of blood parasites, or from the tissue of the host, as in the case of some intestinal worms which feed on the cells composing the wall of the intestine. In any case the host expends at least the extra energy necessary to procure and digest the food taken by the parasite, and this extra labor will be directly in proportion to the amount of food taken, or in general to the size of the parasite and to its fertility.

In the second place the parasite occupies a certain amount of space, and correspondingly reduces the calibre of the tube in which it lives. Unless a considerable number are present this is hardly a practical stoppage for the alimentary canal, although in several recorded cases death has followed occlusion of the canal by a mass of ascarids, and in the case of the blood system a vessel may be closed or a clot formed by the presence of even a very few parasites.

In the third place active parasites will, by their movements, give rise to a certain amount of irritation and inflammation of the membranes over which they move. This is in some ways, perhaps, the most serious trouble which a few parasites can cause, and it is much increased if in the special case the parasite obtains its food at the expense of the tissues of the host, that is, if it tears or consumes the walls of the cavity in which it lives. A secondary, though possible, result of this manner of living is the liability of rupturing some blood-vessel, with consequent serious results, as in the case of certain lung flukes which may chance upon some large blood-vessel and in this way produce even fatal hemorrhage. In the alimentary canal a single ascaris may perforate the wall and induce fatal peritonitis, as has been observed several times in recent years. It is evident, then, that no more than a single active parasite may be dangerous, and that it is always some tax on the domestic economy of its host. Of course, the effect of a microscopic worm in the alimentary canal of an elephant will be so small that it could hardly be calculated in any way; but this reasoning should not be extended too far. The disturbance produced in the human system by a single tapeworm is sufficient to call for prompt measures to remove it.

Recent studies have demonstrated the presence of hæmoglobin in the alimentary canal of many nematode parasites, the pathological effects of whose activities must be counted much more important than heretofore estimated by reason of this blood-sucking habit. Thus in cases of uncinariasis the amount of blood lost from myriads of minute hemorrhages imparts a characteristic reddish-brown color to the fæces, the intestinal wall becomes seriously affected and affords places of easy attack for any pathogenic germs which may be present. This indirect damage may be very serious in the individual instance, and may include primarily or secondarily undesirable retrogressive or progressive histological changes, inflammatory processes, and disturbances in the circulation.

Another source of danger from parasites is one which has long been surmised but only recently demonstrated. A number of investigators have shown that various Cestoda, Acanthocephala, and Eunematoda contain definite poisons (toxins) which when extracted and employed experimentally affect particularly the nervous system and the formation of blood. The continued formation and giving off of such a substance would explain the apparently excessive results of parasitism in some instances, results which are shown prominently in reflex nervous symptoms such as have been noted under Argas (*Arachnida*), and Tænia (*Cestoda*). In a certain proportion of cases pernicious anæmia is the result of this toxic effect, and is accompanied by a mortality of seventeen per cent., according to one report regarding Bothriocephalus. Whether the poison is elaborated by the parasite or is produced by pathological processes in the worm or by its death, as well as the ground for the variability in the toxic action of different specimens, are questions as yet undecided. It has been shown, however, that extracts from different species of helminthes vary considerably in toxic power. Vaullegrard has isolated two toxic principles, one of which acts upon nerve centres and the other upon muscles, and many symptoms produced experimentally by the injection of these substances are analogous to those manifested in parasitic disease. According to this chemical theory, the troubles caused by parasites are due to the formation of toxic substances more rapidly than their elimination by the host, and their consequent accumulation in the system.

It is noteworthy that eosinophilia has been recorded as a frequent if not universal symptom in parasitic infections. From 15 to 50 per cent. of eosinophiles in trichinosis, 10 per cent. in uncinariasis, 15 per cent. in oxyuris infection, and 20 per cent. in ascarid infection are average figures. The percentage varies greatly and does not appear to be constant, while it is present in other pathological conditions as well.

Life History.—Normal parasitism is related to the life history of the parasite with peculiar intimacy. Among accidental parasites the animal seems to continue the usual method of multiplication under the changed conditions. Thus Oerley was able to colonize *Leptodera pellio* in the vagina of mice where they reproduced normally. But in case of the well-known *Rhabdonema nigrovenosum* of the frog the parasitic generation alternates with a free living generation, and the two are distinguished only slightly in structure but radically in method of reproduction, since the one is diœcious and the other hermaphroditic. In the case of the parasite of Cochin China dysentery also, *Strongyloides stercoralis*, there is a hermaphroditic parasitic generation and a diœcious free-living generation, in which the individuals differ noticeably from the first. Alternation of generation is not infrequent among true parasites, but it usually bears a different relation to the life history, and one which will be clear after the examination of the simpler cases.

In the simplest case which is exemplified by many of the Nematoda parasitic in the alimentary canal the eggs reach the exterior with the fæces of the host, and in them or in water undergo development until after a brief period of growth, either still enclosed in the protecting egg membranes, as is the case in *Ascaris lumbricoides*, the common stomach worm, or as a free-living form in the water, the larva is ready to be reintroduced into the human alimentary canal. Then it undergoes its transformation into the adult, which is usually only growth, and the formation of the reproductive organs which are present in the larva in the form of a single cell or group of cells near the centre of the body, often so insignificant in the undeveloped condition as to escape observation. This type of development may be somewhat complicated by the sojourn of the parasite in one region of the canal, where it passes through the earlier stages of development and becomes sexually mature before seeking its definitive location. Such is the case in the pinworm, *Oxyuris vermicularis*, which grows to sexual maturity in the ileum, while the pregnant females migrate to the rectum in order to make periodic excursions to the perineum for oviposition.

A more complicated development is illustrated by the Guinea-worm, *Filaria medinensis*, in which the embryos set free into the water seek out a new host and enter its body in order to pass through the early stages of development there. After having attained a certain stage of growth in this host the larval parasite is ready for introduction into the final host, in which it reaches sexual maturity, and this change is effected probably by chance. The host in which the sexually mature parasite occurs is known as the primary, while the secondary is that in which the larva is found.

In the extreme case the life history is so modified that the parasite never reaches the external world, but passes from one host to another directly. Here the ultimate extreme of the parasitic habit has been attained. As illustrations of this several species of *Filaria* and *Trichinella* may be instanced. In *Filaria Bancrofti* the adult is parasitic in lymph glands and the embryos are set free in the blood stream. From this they are sucked out into the body of a mosquito and there undergo early development, only to be reintroduced at a later stage into the body of a new host where the mosquito is biting. In *Trichinella spiralis* the encysted larvæ in flesh are set free in the stomach by processes of digestion. They wander into the duodenum, and after attaining sexual maturity the female penetrates a villus and sets free the embryos which, reaching the muscle tissue through the agency of the blood current, encyst there and await transference to a new host. Thus in both cases no part of the life history takes place in the external world, and the transfer of the parasite is dependent upon the carnivorous or blood-sucking habit of the animal which functions in the one case as secondary host and in the other alternately as primary and secondary host, but in different organs.

A still more complicated relation is found in the majority of Trematoda and in some Cestoda when the change of host is associated also with an alternation of a sexual with an asexual generation. In most Cestoda the eggs develop into an embryo which in the secondary host gives rise by metamorphosis to a peculiar larva, the bladder worm; and this after its transfer to the primary host develops into the adult tapeworm. The relation between primary and secondary host here is generally that of food and feeder. Thus the bladder worms of the two most common human cestodes are found in the flesh of cattle and hogs respectively and develop when introduced into the alimentary canal of man into the adult tapeworm. Though somewhat complicated by radical changes in form, the process is generally regarded merely as a metamorphosis. The case is somewhat different in those forms, as, for instance, *Tænia echinococcus*, in which the bladder worm proliferates, forming not a single head merely, but several or many, from each of which when introduced into the proper host there may develop an adult cestode. Here the larva in the secondary host multiples asexually, while the adult in the primary host reproduces sexually. The change of hosts is accompanied by an alternation of generations or metagenesis.

In the Trematoda one finds the same alternation of generations coupled with change of hosts, only that the asexual generation may be repeated and the life history further complicated by the introduction of a new host, the tertiary, in which a stage of the development is passed. Among those forms of which the life history has been ascertained great difference obtains in detail; of the species parasitic in man the development is as yet known only in part so that the general statement may suffice and reference be made for details to the special account of the group given elsewhere.

Mode of Introduction.—The life history often gives a clew to the means by which the parasite gains introduction into the human host. Thus the discovery of bladder worms or of larval *Trichinellæ* in pork suggested at once the manner of infection, namely, by eating the flesh containing these larval stages without the flesh having been subjected during preparation to conditions such as to kill the larvæ. This method of infection, namely, the introduction of encysted larvæ, is characteristic for the Cestoda. Those species most common as adults in man among civilized nations are obtained directly from articles of food, as *Tænia saginata* from beef, *Dibothriocephalus latus* from fish; other less frequent species as *Hymenolepis diminuta, Davainea madagascarensis,* and others of which the larval stages are found in insects (cockroach, beetle, meal worm) owe their introduction perhaps to the chance inclusion of such infected insects in bread, puddings, or other similar articles of food.

Disregard of personal cleanliness on the part of the individual, the habit of biting the finger-nails, and among children the practice of sucking fingers or toes serve to infect such with the eggs or embryos of many parasites or to increase an infection already acquired. In this way there is introduced the larva of *Dipylidium caninum* which lives in the dog and cat fleas, the eggs of *Ascaris canis,* the dog and cat round worm, eggs of *Oxyuris vermicularis* which are deposited upon the perineum of the host, eggs of *Cysticercus cellulosæ* when the adult is present in the same host, and many other species. Contamination of hands with eggs from dirt and consequent infection of the individual is common in children and field laborers, and may introduce any form of which the eggs are capable of causing the direct infection; these forms are *Ascaris lumbricoides, Trichocephalus trichiuris,* and other Nematoda.

The introduction of eggs and embryos takes place in the majority of cases, no doubt, through the contamination of the water supply. Almost all the eggs of the helminthes develop in standing water, and primitive methods of obtaining drinking-water from pools afford the best means of disseminating the species. Salads and other foods eaten uncooked serve as further means of infection, especially in those regions where it is customary to use human excrement to enrich the soil, or where the water supply of the village is dependent upon infected sources.

Among the important parasites which reach the human system as eggs in water or on uncooked vegetable food are of the Cestoda: *Cysticercus cellulosæ,* the larva of *Tænia solium, Echinococcus polymorphus,* the larva of *Tænia echinococcus;* of the Nematoda: *Ascaris lumbricoides, A. canis, Oxyuris vermicularis, Trichocephalus trichiuris;* of the Linguatulida: *Pentastoma denticulatum, Porocephalus constrictus.*

Of those which as larvæ attain the human host in the same manner one may list all the Trematoda parasitic in man, and of Nematoda *Strongyloides stercoralis* and possibly *Uncinaria duodenalis,* though according to the studies of Looss the latter seems to bore its own way actively into the body of the host.

The part played by chance in the introduction of parasites is very large. Grubs, hairworms, maggots, and even tapeworms have been taken from wells and from running water. The same forms occur frequently in various kinds of fruit; others in old or carelessly handled meat, also mites in cheese and fruit; and any or all of these may at times reach the human alimentary canal, where according to their adaptability they become occasional, accidental, or pseudoparasites. Their presence may be made known at once by adverse conditions, or they may remain long undetected so that their source is fully unknown. They may reach peculiar locations, as is shown by the flesh fly maggot taken from an abscess in the middle ear, which it had in all probability reached by active migration through the Eustachian tube, having been introduced into the throat with a piece of meat.

Factors Controlling the Abundance of Parasites.—The life of man in communities led at first to a large increase in the number of parasites and to frequent epidemics; and both of these results were due to conditions resulting from the communal life. Of primary importance is the impure water supply which semicivilized communities are wont to draw from the nearest pool. The minute, well-protected eggs of parasites distributed in fecal matter everywhere (for such communities are not exacting in their demands for the disposition of waste) are carried by rain water and distributed over large areas contiguous to the settlements and contaminate generally the surface water of the district. In case the parasite develops directly, the human host becomes infected by the use of this surface water; and if it is a form requiring a secondary host, the same conditions give it easy access to the forms which serve as such, since these are largely domestic animals. The close relation of the abundance of parasites to the water supply is well illustrated by the case of *Bothriocephalus latus.* This form is very common in a few regions in Europe, all of which are proximate to bodies of water. The intermediate host is a fish, and the very means adopted by civilized communities for removing danger of contamination from waste, namely, the sewage system, became the medium through which the eggs and embryos were carried into the lake. There they found suitable secondary hosts in the fish which subsequently reached the city markets further to infect the populace. The life cycle was complete within narrow geographical limits, and the element of chance which plays a large part in limiting the numbers of parasitic animals was reduced to lowest terms.

The dangers of parasitic infection in communal life, which pays little attention to the amount and character of surrounding surface water, is also illustrated by the spread of malaria, elephantiasis, and yellow fever, which depend upon the abundance of mosquitoes bred in this casual water. It has been abundantly shown that criminal carelessness on the part both of individual and community has multiplied breeding places and contributed materially to the spread of these diseases. Even the invention of protective screens has not been able to cope with these aggravating carriers of disease.

The habit of the isolated individual is also that of the community, even such as may be well advanced in the social scale, namely, to deposit human excrement indiscriminately. This method, which even to-day is practised in some parts of the United States, is well calculated to give to eggs of parasites a maximum opportunity for development. The same opportunity is afforded when the Chinese gardener employs for the enrichment of his garden patch human excrement from the neighboring village.

The same massing of individuals which has made the community more liable to parasitic infection plays its part in the infection of the secondary hosts, especially those which are domesticated animals. If the ground on which cattle are grazing becomes infected by tapeworm eggs, the entire herd may receive bladder worms. The infection of a single hog with trichinæ means the contamination of the entire group if the pernicious habit is followed of feeding to others the remnants of a slaughtered animal. Just here is the chief reason for the strong condemnation which has been visited upon local slaughter-houses. They regularly feed the offal to hogs, and by so doing further the spread of such parasites. In the large packing establishments the requirements of modern industrial success are met by regulations which cure the evils referred to. All remnants are used and are subjected to processes which destroy whatever parasites may be included. Under these conditions one may safely predict the gradual disappearance of parasites, especially with the co-operation of certain factors not yet mentioned.

In addition to municipal features as noted, personal habits play an important part. Cleanliness of person and hands, coupled with careful ablution not only of the person but also of the various articles of food, reduces the percentage of parasitic infection. A simple infection of *Trichocephalus* becomes manyfold greater by the accidental transfer of eggs from the skin near the anus, where they are deposited, to the mouth. The reality of such supposed auto-infection is proved by the high degree of infection among insane and defective classes which are known to exercise little care over personal cleanliness. No doubt many eggs of parasites are introduced on salads and other uncooked foods which are eaten without sufficiently careful cleansing previously.

The employment of footgear and hand coverings is influential also, because it reduces directly the likelihood of infection from eggs of parasites contained in earth, etc., which with uncovered hands become temporarily imprisoned beneath the finger nails of the field laborer. These coverings may also play a considerable part in preventing infection with *Uncinaria* if the observations of Looss are confirmed that the larvæ enter the body by an active migration through the skin, chiefly of the hands and feet, with which they come in contact in the case of field laborers.

Another factor which has tended to reduce the percentage of parasitic infection is the less intimate association of the more highly civilized individuals with domestic animals, especially dogs. The parasites of these animals, and in particular one species, *Tænia echinococcus*, possess great clinical importance for man. Not only is it apparently less frequent than previously, but also its frequence is certainly greatest now in those regions in which the inhabitants live most familiarly with their dogs. It should be noted also that the initial infection of the dog is prevented by keeping from it the offal from slaughtered cattle and sheep.

Probably more influential than any other factor in determining the reduction in degree of parasitism is the use of cooked food. A large part of the flesh food of semicivilized man is eaten raw or only partially cooked, in which condition the larval parasites are capable of development to the adult on reaching the alimentary canal of the new host. Were all animal food eaten only when thoroughly cooked, the common tapeworms and the dreaded *Trichinella* would cease to have clinical importance. The abundance of *Tænia saginata*, the beef tapeworm, where beef is eaten raw, of *T. solium*, the pork tapeworm, where raw ham is a delicacy, and of *Dibothriocephalus latus*, the broad tapeworm, where partly cured fish is eaten uncooked, furnishes the demonstration of the proposition advanced. And so long as pork is eaten uncooked cases of trichinosis will occur, whatever means may be taken to reduce the danger by meat inspection.

That factor which is about to be considered is destined to play the greatest rôle in the limitation of parasitism; it is the intellectual, and by it is brought about the determination of a rational hygiene and its application by the individual. National prejudice or established custom can oppose its introduction only temporarily, and it must ultimately succeed in reducing to lowest terms the parasitic infections of man and the important food animals.

Henry B. Ward.

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References to the important works consulted may be found under *Arachnida, Cestoda, Hirudinea, Mosquitoes in their Relation to Human Pathology, Nematoda, Protozoa*, and *Trematoda.*

PARATHYROIDS. (NORMAL AND PATHOLOGICAL ANATOMY.)—In 1880 Sandström discovered the presence of small glandular organs on the posterior surfaces of the lateral lobes of the thyroid. He found these to be of constant occurrence, and from their structure regarded them as embryonic thyroid tissue; he accordingly named them *glandulæ parathyroideæ.* A year later, the same organs were independently discovered by Stieda in embryos of the pig, and by Baber in different animals. The former regarded them as carotid glands, the latter as embryonic thyroid tissue. But little attention was paid to these glands until 1891, when Gley asserted their importance. In the few years immediately following, his statements were supported by numerous observers. In 1895 the first careful study of the minute anatomy of the parathyroid was given by Schaper. Numerous experimental investigations followed, both in normal and thyroidectomized animals, showing the physiological importance of these structures. Various names have been proposed for them: "*epithelial bodies,*" "*accessory glands,*" "*accessory thyroids,*" "*glandules thymiques,*" etc.; the original designation *parathyroid* has the advantage, however, that the organs are not thereby confused with the accessory glands having the true thyroid structure.

As to the physiology of the parathyroids and their function no absolute knowledge has yet been obtained. It was first believed that they had a direct connection with the thyroid, and could compensate for it. Later experimental investigations in transplantation and extirpation, as well as in feeding with gland substance, have shown that the parathyroids have a function distinct from that of the thyroid. The loss of the thyroid leads to a chronic disease, that of the parathyroids to an acutely fatal disease. Feeding with gland substance is effective only in case of the administration of the same gland substance as that of the organ affected; thus thyroid feeding is of value only in case of the loss of the thyroid, and parathyroid feeding only in case of loss of the parathyroids. In transplantation, both thyroid and parathyroid preserve their characteristic structure.

The various investigators are not yet agreed as to the embryology of these glands, but it may be regarded as proved that the parathyroid bodies lying outside of the thyroid have an independent *Anlage* in the fourth gill pouch. In some animals there occurs constantly an epithelial body included in thyroid tissue, which probably arises from the third gill pouch. This internal epithelial body occurs so rarely in man that its presence may be regarded as a probable anomaly of development. Further, the parathyroids arise from single symmetrical *Anlagen*, and their occasional multiplicity is to be ascribed to a secondary snaring off.

The parathyroids occur usually in pairs; sometimes one on each side, or two on one side and one on the other. The writer has also found three upon one side. The total number observed has never been greater than four.

In size they vary greatly, but they are usually very small; the average, as found by the writer, being about 7 mm. long, 2–3 mm. broad, and 1.5 mm. thick. The average weight is about 0.2–0.3 gm. They are often almond-shaped, having one end recurved; but the shape not infrequently suggests the spleen. At other times they may be flat, cylindrical, or round. Their color is usually pale brown, but may be brownish-red or bluish, so that they are easily mistaken for hæmolymph glands. They usually lie behind the lower poles of the lateral lobes of the thyroid, separated from the thyroid tissue by connective tissue, their convex surfaces lying in slight depressions on the under surface of the lobes. Not infrequently they are found below the thyroid, even as low as the level of the clavicle. It is often very difficult to recognize the parathyroids at the autopsy; therefore all of the glandular structures in this region should be removed for microscopical examination. It is of advantage, in case the organs are not easily found, to take out the neck organs *in toto* and fix them in formalin. After fixation the dissection of the region behind and below the thyroids usually results in the determination of the exact location and relations of the parathyroids, their brown color becoming more prominent in contrast to the white adipose tissue about them. By following up the branches given off from

Trematoda

Petrus Servius reported the first case as occurring at Rome.

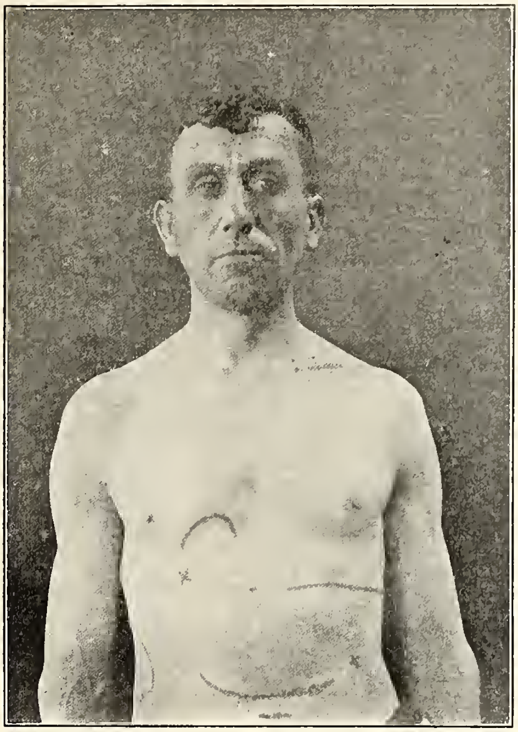

FIG. 4770.—Photograph of Schüppel's Case of Transposition of the Viscera. The X below right nipple indicates the position of the apex beat. The curved line above shows the absolute heart dulness. The straight line below the left nipple indicates the upper border of the liver dulness. The X below this line indicates the lower border of the liver dulness. The curved line above the navel indicates the greater curvature of the stomach. The curved line low down on the right side indicates the splenic dulness.

Küchenmeister, up to the year 1888, collected 149 cases. The majority of these were discovered in the anatomical laboratory and on the post-mortem table. Pie in 1895 increased the number of reported cases to 190. Loehte up to the year 1894 collected 13 cases of partial transposition of the viscera. In more than half of these very poor descriptions were given.

An attempt to collect all the cases of situs viscerum inversus is extremely difficult and unsatisfactory, because they are reported in the literature under numerous headings. Perhaps something like 300 of these cases have been reported.

Until recent years cases of transposition of the viscera have been discovered, studied, and reported chiefly by anatomists and pathologists. Judging from my own personal experience with these cases, and from that of a large number of prominent clinicians and anatomists to whom I addressed letters of inquiry regarding their experience with transposition of the viscera, it would seem that the pendulum has swung about of late years, and that now a much larger percentage of cases of transposition is discovered by the clinician. This fact is a natural result of the much more frequent and careful physical examinations that are now being made. However, even with this improvement, all physicians know that a very small percentage of even sick people submit to careful physical examination, and that the percentage of the entire population who are thus examined is extremely small.

Since the spring of 1897 I have seen in hospital and private practice six cases of transposition of the viscera. It is rather a remarkable fact that three of these cases were seen within the short period of six months. I am also personally familiar with three other cases of situs inversus, discovered in the living subject by members of the internal medical staff of the University of Michigan, two by Dr. Warthin, and one by Dr. Cowie.

These cases have been reported in detail in the *American Journal of the Medical Sciences*, November, 1902, and in the *Vaughan Festschrift*, 1903.

In reply to my letters the following facts were gleaned: Five well-known internists and four professors of anatomy had never seen a case of transposition of the viscera. In the remaining letters 37 cases were reported. All save 6 of these were discovered during life. In this country, at least, cases of transposition are nowadays much more frequently discovered during life than after death. Note the contrast between Gruber's report and my own. Of his 79 cases only 5 or 6 were discovered during life. In my collection, which simply covers the cases reported in the letters referred to, together with those with which I am personally familiar, are 46 cases, of which 40 were discovered during life.

Method of Examination.—Careful inspection, palpation, percussion, and auscultation of the chest are of course prime essentials. The failure to find the heart apex and heart dulness on the left side most often puts one on the right track. A careful examination of the right chest may then reveal a dextrocardia. This is at once a key to the physical condition. An absence of liver dulness is then detected in the right hypochondrium. It is sought for and discovered in the left hypochondrium; the splenic dulness will then be found in the right midaxillary line.

The position and outline of the stomach may be demonstrated by inflation or by the use of the gastrodiaphane; the same is true of the sigmoid. x-Ray examination of the heart with the fluoroscope easily demonstrates the right-sided position of this organ. (See Fig. 4771.)

Theories Explaining the Development of Transposition.—These are chiefly of interest to the embryologist and anatomist, and will hardly be understood except by those who have devoted special study to embryology. The following are some of them.

Von Baer explains transposition by the turning of the embryo in the opposite direction; that is, the embryo normally lies on the left side of the umbilical vesicle; but if it lies on the right side, then we have transposition. According to him this occurs at the beginning of the developmental period.

Förster considers situs inversus a malformation in which the transposition of the anlagen takes place in the first embryonal formation. In the double monster the fœtus of the right side shows a complete transposition, while the fœtus on the left side shows a normal situs.

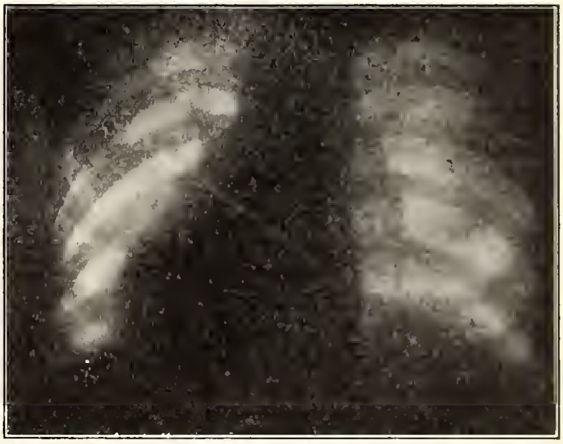

FIG. 4771.—Radiograph showing Transposition of the Heart to the Right Side. (Schüppel's case.)

Rindfleisch believes that a spiral turning of the blood column is responsible for the displacement of the heart. Normally it flows from left to right, but in situs inversus an opposite direction must obtain. The asymmetry of the heart is made responsible for all asymmetry in the animal body.

Virchow emphasizes the influence of the umbilical cord. In situs inversus it is wound spirally to the right; in situs solitus to the left.

Küchenmeister thinks that the location of the fertilized germinal disc at the surface of the egg is the essential thing. The normal situs in single birth probably depends upon growth of the germ from below upward, instead of from above downward. He says that from this it must be self-evident that the turning of the embryo has been inverted. This must also affect the later spleen side and the side of the arterial heart. Concerning the congenital partial situs viscerum, solito inversus, which shows itself either in the chest or in the belly, but not in both places at the same time, he believes that the growth on the whole follows the type for the situs inversus. The rarer partial situs is an inhibition formation which grows according to the type of the normally projected embryo.

Martinotti in the situs transversus of the single born emphasizes the condition of the vena omphalo-mesenterica, first mentioned by Dareste. The direction which the heart loop takes depends upon the dissimilar growth of the two halves of the vascular area. Under normal conditions a dissimilar formation of the two halves exists. The left omphalo-mesenteric vein is more developed than the right; the right gradually disappears. The heart reacts in a very sensitive way toward the cause of situs transversus.

Marchand says that the loop formation of the vena omphalo-mesenterica about the intestines under normal conditions prevents the intestines from slipping toward the right. So a right turning takes place if the loop formation is absent. He considers a left-sided persistent vena omphalo-mesenterica the cause of the right position of the stomach. In a more recent monograph Marchand states it as his belief that the development of the vena omphalo-mesenterica can have no influence upon the rotation of the stomach.

Lochte advances the view that the growth of the organ considered in the sense of situs solitus is associated with a persistence of left-sided omphalo-mesenterica and umbilical veins, while those of situs transversus totalis, on the other hand, are associated with corresponding right-sided veins.

To the clinician transposition of the viscera presents many interesting problems in differential diagnosis. The displacement of the heart to the right makes it necessary to examine the lungs and pleura carefully, in order to exclude acquired displacement. The discovery of an enlarged area of dulness in the left hypochondrium suggests a number of possibilities. It is most likely an enlarged spleen—either of leukæmia, malaria, splenomegaly, or some other disease. This point is illustrated by actual cases in practice. In Munson's case the diagnosis of an enormously enlarged spleen had been made; and the displacement of the heart was thought to be due to dilatation.

In the normal patient it is a very common experience to find an entire absence of liver dulness in the right hypochondrium. It is also common to find that the apex beat is neither seen nor felt on the left side, especially if the patient is quiet and in the horizontal position. Heart dulness is also frequently absent. So it is easy to understand how these cases of transposition often are overlooked.

It is possible to mistake an aneurism of the arch for a dislocated heart. This fact was recently brought to my attention.

Gruber refers to the following errors in diagnosis. In one case of transposition a pain in the right hypochondrium led to the diagnosis of a chronic inflammation of the liver. In another case a soldier was wounded in a duel, in the right hypochondrium; from the position of the wound and the vomiting of green fluid it was thought that the liver had been penetrated. In a third case, in the Würzburg clinic, the transposed liver was diagnosed as a spleen tumor. In a fourth case, one of cancer of the pylorus, in a transposed stomach, the hard tumor felt deep in the left hypochondrium was thought to belong to the left part of the stomach or the pancreas.

In appendicitis developing in a patient with transposition of the viscera the signs and symptoms would of course be located on the left side instead of on the right side. The surgeon would choose Monroe's point instead of McBurney's point for the site of his incision.

Gruber arrived at a number of interesting conclusions from a study of 79 cases. "Concerning the sex there were 49 men, 19 women, and 11 in which sex was not mentioned. These individuals lived as long as those with normally placed organs. Five of the 19 women lived to an age between seventy and eighty-four.

The women were normally fruitful. One gave birth to twelve children. Among the 79, 4 died an unnatural death, and only 4 were extremely malformed. There was transposition of *both* chest and abdominal organs in 71; of the abdominal organs alone in 8. In the first kind the transposition was complete, in the latter incomplete.

The lungs were transposed in 35 of 71 cases; the right had two lobes, and the left three. In 2 cases they were not transposed; in 2 both lungs had two lobes; in *one* the right had one lobe, and the left two lobes.

Curvature of the dorsal portion of the spine is mentioned in only 11 cases. In 7 of these it was to the left, in 4 to the right as normally.

We cannot draw the conclusion that persons with transposition are more likely to be left-handed than those with normally located viscera.

The position of the testicle was mentioned only 7 times. In 4 the right was lower, in 1 the left. In 1 the left had not descended.

The lower position of the right testicle is unimportant as a sign of situs inversus.

In only 9 cases were there notes on the position of the kidneys. In 7 the left was lower, in 2 the right.

In 32 cases in which the vessels arising from the arch of the aorta are mentioned, these were transposed 29 to 30 times.

H. Steinhauser mentions the fact that in the operation of œsophagotomy, it is well to know that the œsophagus lies over the right trachea in persons with transposition.

In situs partialis the transposition of the abdominal organs may be very irregular. In one case the stomach and duodenum were normally located, while the other organs were transposed. In another case the liver alone was transposed.

In 1888 a case of pure dextrocardia with congenital pulmonary stenosis, without malposition of the viscera in general, was shown to the Vienna Medical Society by Dr. Gruss. In discussing the case, von Bamberger concurred in the diagnosis, and remarked that Professor Schrötter had lately stated that no single case of pure dextrocardia had ever been proved, whereas all anatomists of experience, for example Rokitansky, Friedberg, Förster, *et al.*, had mentioned such cases, and he himself had seen two.

The above quotation emphasizes the fact that partial situs is a much rarer condition than complete. If the transposition is located in the abdominal cavity, it will most likely be overlooked in the physical examination.

James Rae Arneill.

TRAUMATOL—iodocresol, orthocresol iodide, $C_6H_4.CH_3.OI$—is a reddish, odorless, insoluble powder which is used as an antiseptic substitute for iodoform in wounds and ulcers. It is an efficient drying powder and deodorizer. *W. A. Bastedo.*

TREMATODA.*—The class Trematoda, or Flukes, constitutes one of the prominent subdivisions of the branch or phylum Plathelminthes, the characteristics of which were outlined under the Cestoda. The group was recognized as distinct in 1800 by J. G. H. Zeder, a practising physician in Germany, who with great clearness of vision separated the then accepted class of Helminthes or intestinal worms into five groups of closely related forms. These groups received in 1809 at the hands of K. A. Rudolphi, the celebrated Berlin helminthologist, the scientific names of Nematoda, Acanthocephala, Trematoda, Cestoda, and Cystica. The latter have since been shown to be immature stages of the Cestoda, and C. Vogt in 1851 demonstrated the unnatural character of the association Helminthes, making as a natural group the flatworms in which are now included the flukes, the tapeworms, and the free living flatworms, as three great classes of the phylum designated Plathelminthes.

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* A general discussion of parasitism and its effects is to be found under the heading *Parasites*.

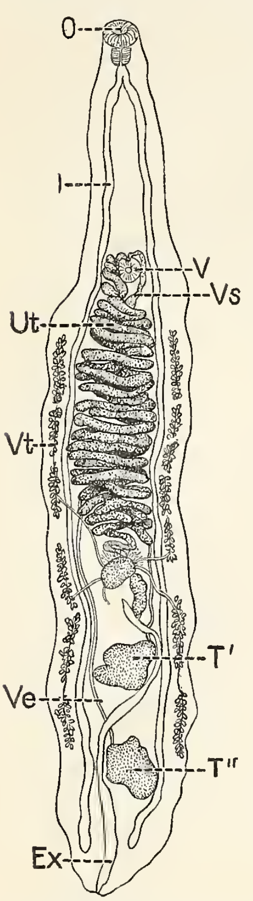

Fig. 4772.—*Opisthorchis pseudofelineus* Ward. From liver of cat. *Ex*, Excretory bladder; *I*, intestinal crura; *O*, oral sucker; *T'*,*T''*, testes; *Ut*, uterus; *V*, ventral sucker; *Vt*, vitellaria; *Ve*, vas efferens; *Vs*, vesicula seminalis. × 7. (Original.)

In certain features, such as the simple body, the presence of an alimentary canal, and in some cases even of special sense organs, the Trematoda stand much nearer the free living forms than do the Cestoda, although all of the species included in both classes are parasitic. The consistent parasitic habit, in which the flukes resemble the tapeworms, is varied by a modification in degree among the flukes which serves to show their relation also to free living species and contrasts strongly with the intensive endoparasitism of the Cestoda. Thus among the flukes there are not only the endoparasitic species, but also such as are ectoparasitic and preserve in some degree those features of free living forms that are lost with the assumption of endoparasitic existence. Withal the group is a well-defined one, and manifests greater uniformity in structure than the Cestoda, while it also embraces both fewer species and fewer human parasites than the latter class.

In form the Trematoda are generally flattened and elongate, more rarely cylindrical, conical or irregular, with plane ventral surface on which are located the sexual pores and arched dorsum. The mouth is at or near the anterior tip of the body and the excretory pore is similarly related to the posterior end. The mouth is nearly always surrounded by an oral sucker, and other suckers may occur on the ventral surface, at the posterior end, or more rarely on the margin or dorsal surface. In connection with the suckers chitinous hooks or anchors are found as additional organs of attachment, and the exterior of the body is often covered more or less completely by scales or spines of varying form and size. Most flukes are comparatively insignificant in size, measuring only a few (1 to 15) millimetres in length, though rare species largely exceed both limits.

A cross section shows that a body cavity is wanting. The trematodes belong to the group of forms in which the space between all organs is filled up by parenchymatous tissue, giving a firm consistence to the mass. The exterior is bounded by a homogeneous membrane of varying thickness known as the cuticula, which actually is formed by the fused bases of cells lying deeper in the tissue, but which presents the appearance of a basement membrane. It was formerly construed as such, and the trematodes were believed to be without an epithelial covering in the adult condition. As a matter of fact the pyriform epithelial cells lie in bunches between or within the diagonal muscles, and are connected by numerous fine processes with the basal surface of the so-called cuticula. Some of these cells are especially developed as unicellular glands.

The dermomuscular sac lies just within the cuticula and consists of layers of circular, longitudinal, and diagonal fibres which surround the body, though of varying thickness in different regions. Running obliquely from one surface to the other occur also dorsoventral or parenchymatous muscles which are inserted on the cuticula. Especial development of the muscular layers is found in the suckers, which consist of muscle fibres extending in three directions and designated as equatorial, meridional, and radial; these correspond to the circular, longitudinal, and dorsoventral muscles respectively. In addition one finds a special set of muscles radiating from the sucker through the tissue. In certain cases at least special muscles are developed in connection with the reproductive organs, with the hooks, and even with the surface spines, as in the common liver fluke. The high development of the muscular system, associated with the absence of special skeletal structures, combine to make the form of the flukes extremely mobile and variable. Locomotion is achieved by means of the body musculature and the suckers, aided in rare cases by the cuticular spines already mentioned.

An alimentary canal is always present and forms the ultimate distinctive feature between Trematoda and Cestoda. In all cases it has but a single opening, the mouth, which lies at the anterior tip of the body, or more rarely on the ventral surface and in all higher forms is surrounded by the oral sucker (*O*, Fig. 4772). In lower members of the group, two or more suckers may lie near the oral opening or the latter may be entirely unarmed. In form the alimentary canal may be rhabdocœl, though much more frequently it is of the triclad type. In the latter case one can distinguish an initial unpaired region variable in length, which extends posteriad from the oral opening and is called the œsophagus. It is thin-walled and not digestive in function, though frequently numbers of unicellular salivary glands are connected with it. Near its oral end a prominent sphincter muscle forms a bulbous mass known as the pharynx. By its action the oral sucker is closed posteriorly to act as a simple organ of prehension, or stands in open communication with the canal, for which it serves as an aid in the ingestion of food.

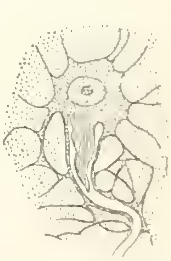

Fig. 4773.—Flame Cell and Excretory Tubule of *Azygia tereticollis* (R.) × 700. (After Looss.)

The simple œsophagus divides into two intestinal crura (*I*, Fig. 4772), which form the digestive and absorptive region of the canal. They are blind sacs, usually symmetrically placed right and left, but of variable length and character. In some genera they are so short as not to reach the sides of the body; in other cases they extend to the posterior end, and may even be connected by several commissures or anastomoses. Usually the crura are of uniform calibre throughout, and yet in some genera they manifest an irregular wavy outline, or even possess numerous lateral diverticula which may branch again and give the system a dendritic aspect. The endoparasitic forms subsist on the intestinal contents and secretions of the host, but also ingest epithelial cells and blood, thus giving rise in some cases to severe hepatic or intestinal disturbances, the gravity of which is proportionate to the extent of the invasion.

The excretory system agrees in general with that of the Cestoda. One finds a variable number of primitive nephridia or "flame cells" (Fig. 4773), scattered throughout the tissue. These cells are stellate in form, with a huge bunch of cilia which lie on one side in a narrow canal. The constant motion of the group of cilia simulates the flickering of a candle flame, whence the name. The tubules from these flame cells unite into larger ducts, and ultimately combine in a single vessel, which opens at the posterior end of the body by a simple excretory pore (*p*, Fig. 4774). The final vessel may be short and expanded or a longer median canal. In both cases it apparently functions as an excretory reservoir or bladder (*ves*, Fig. 4774). The system, which was formerly called a water vascular system, contains a clear fluid, sometimes slightly tinted, with occasional granules or concretions. It is produced by the activity probably of the terminal cells, the cilia of which serve to maintain movement. The presence of uric acid in the fluid is sufficient evidence of its excretory nature.

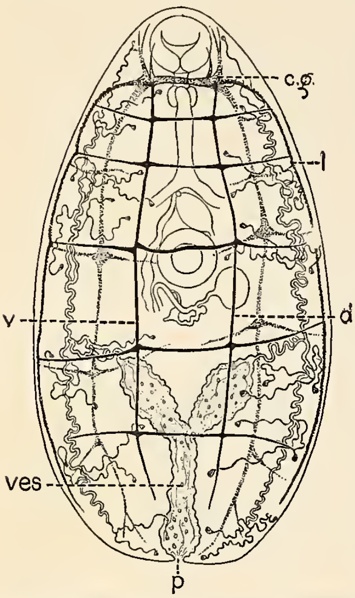

FIG. 4774.—Nervous and Excretory Systems in *Opisthioglype endoloba* (Duj.). *c.g.*, Cerebral ganglion; *d*, dorsal, *l*, lateral, *v*, ventral nerve trunks; *p*, excretory pore; *ves*, excretory bladder. × 30. (After Looss.)

The nervous system is poorly developed in accord with the parasitic habit of the group. It consists of two small lateral aggregations of ganglion cells (*c.g.*, Fig. 4774) near the pharynx which are joined by a ring of fibres that encircles the œsophagus, and of nerves extending anteriad and posteriad from these ganglia. The three pairs passing anteriad are short and innervate the oral sucker with adjacent dermal areas, muscles, and primitive sense organs. The posterior nerves form dorsal, (*d*), lateral (*l*), and ventral (*v*) paired cords. The ventral nerve cords are much the most prominently developed; they join each other near the posterior end as do also the dorsal cords. Circular commissures at somewhat regular intervals unite all three pairs of nerves, and ganglion cells occur most frequently at the points of union, though also rarely elsewhere in the course of the nerves. A dermal nerve plexus is at least often present, and stands in immediate connection with the main nerve trunks. Sense organs, of the most primitive sort, occur in the skin, while in the free swimming larvæ as well as in ectoparasitic forms simple eye spots are found. Other sense organs are not known.

Reproductive System.—The Trematoda are all but universally hermaphroditic, and possess highly complicated organs of reproduction. One of the human parasites illustrates the rare secondary condition of separate sexes, and will be considered under the appropriate heading; here it is sufficient to outline the general conditions.

The testes (*T*, *T*″, Fig. 4772) are usually two in number, symmetrical in size and location, although there may be but a single one, or on the other hand a series of several. These organs are commonly round or oval in outline, with frequent variations toward a lobed condition, or even to a dendritic form. The two vasa efferentia unite sooner or later into a single vas deferens, which may or may not possess an enlarged region used as a seminal vesicle. The duct opens on the surface of the body, or into a genital cloaca at the common genital pore, and the terminal portion of the canal may form by eversion a protrusible copulatory organ. More frequently this region possesses a highly developed muscular organ known as the cirrus, and this with or without the seminal vesicle may be enclosed in a sac denominated the cirrus pouch, and provided with unicelluiar glands (prostata). When highly developed this copulatory apparatus forms a conspicuous organ, and, as has recently been elucidated by Looss, constitutes a valuable taxonomic character.

The female reproductive organs show an unusual specialization in the separation of the germarium, often incorrectly denominated the ovarium, from the vitellaria or yolk glands. The germarium (*G*, Fig. 4775) is small, located ordinarily in front of the testes, and usually round or oval in outline, although it may also be dendritic in form. The vitellaria are paired, highly lobed or dendritic in form, and extended usually along the sides of the body lateral to the intestinal crura. Their extent is of importance in specific determinations. The duct from each vitelline gland tends toward the germarium, and near this organ unites with that from the opposite side in a common yolk or vitelline duct, on which at the junction there is at times an enlargement known as the vitelline reservoir. The short germ duct, coming from the germarium, and the common yolk duct, unite to form a short, slightly expanded tube known as the ootype on the sides of which are found unicellular glands, often crowded together into a mass and collectively denominated the shell gland (*Sg*, Fig. 4775). From the ootype a short inconspicuous canal rises to the dorsal surface; this organ, called Laurer's canal (*L.C.*), is clearly rudimentary, and its significance is not beyond dispute, although it is usually homologized with the vagina of ectoparasitic forms; and, according to recent observations, still functions as such in rare cases. It may bear near the proximal end a bulbous lateral expansion, the seminal receptacle (*R*).

The ootype expands immediately beyond the shell gland to form the uterus (*Ut*), which as a long convoluted tube fills the major portion of the body with its coils crowded with opaque brown-shelled eggs. In the portion of the uterus which lies near the ootype there is usually a mass of sperm, so that the region has been called the uterine seminal receptacle. The uterus terminates in short heavy-walled region devoid of eggs, known as the metraterm. This lies alongside of the cirrus pouch, and opens at the female genital pore on the surface of the body, or into the genital cloaca and serves to receive the cirrus in coition. In these forms cross fertilization is the rule, and cases have been observed in which one individual only functioned as the male as well as such in which both were thus functional. In a few instances self-impregnation has been found. The genital pore lies ordinarily in the median line near the ventral sucker, or between it and the fork of the alimentary canal; but a marginal position, or one near the oral sucker, or even at the posterior end of the body, is also to be found.

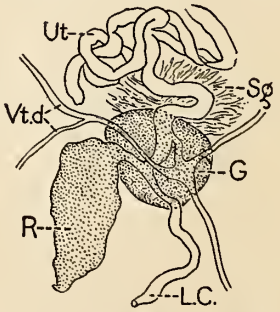

FIG. 4775.—Female Sexual Organs of *Opisthorchis pseudofelineus* Ward. Higbly magnified to show relation of ducts. *G*, Germarium; *LC.*, Laurer's canal; *R*, seminal receptacle; *Sg*, shell gland; *Ut*, beginning of uterus; *Vt.d*, vitelline ducts. (Original.)

In the arrangement of the reproductive organs one finds the double condition designated sexual amphitypy, in which one individual is, as it were, the mirror image of the other. Usually one can be designated as having the normal arrangement, but the relative frequency may be such that neither can be said to be more typical than the other. Such a reversed arrangement was first observed among the Opisthorchiinæ, where it seems to be very common; it has also been shown to exist among the Dicrocœliinæ, and the difference in Paragonimus Westermanii referred to later (Figs. 4782, 4784) may be explained in the same way.

This description obtains for the endoparasitic forms, particularly for the Fasciolidæ, which are of special importance here. In other families, especially among the ectoparasites, somewhat radical differences from the plan outlined may be observed.

The egg of the Trematoda is more or less oval or ellipsoidal, rarely flattened asymmetrically. It is provided with a heavy chitinous shell which is transparent when first formed, but darkens soon in the first coils of the uterus to a deep yellowish-brown, which is almost entirely opaque. In ectoparasitic forms the egg shell possesses a polar filament by which it is attached when deposited; but this is not present in endoparasitic forms. At most one finds an irregular, insignificant protuberance at one pole, such as is present in *Schistosoma hæmatobium*. The shell regularly possesses a cap or lid which is sprung at the appropriate time to allow of the escape of the enclosed embryo. Such eggs may be found in the waste of the body, excreta, or sputa, or may occur adventitiously in various tissues. Under such circumstances they have in the past been diagnosed as coccidia.

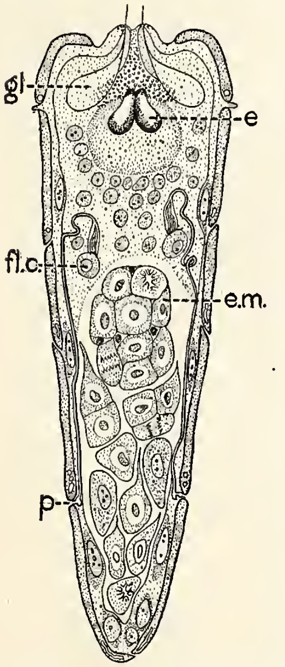

FIG. 4776.—Miracidium of *Fasciola hepatica* (L.); in cross section, showing eye spot (*e*), embryonic cell masses (*e.m.*), flame cells *fl.c.*), cephalic glands (*gl.*), and excretory pore (*p*). Much magnified. (After Coe.)

Development.—When first formed the shell contains the single fertilized egg cell surrounded by a mass of highly granular yolk cells. The latter may be distinct or may be already broken down into an indistinct granular mass. This serves for the nutrition of the embryo during early development. The cleavage of the fertilized ovum begins at once, and ordinarily proceeds so as to bring the embryo to development at the time when the egg, extruded from the uterus of the parent worm, is carried into the external world with the waste products of the host. This is simple since the normal seat of the parasite is the alimentary canal, or some of its outgrowths, liver, lungs, etc., and the eggs are distributed with sputa, fæces, or rarely urine.

The modified environment brings about the opening of the egg shell and the escape of the embryo, which follow experimentally when the ripe eggs are brought into water at suitable temperature. The embryo (Fig. 4776), which is designated a miracidium, is somewhat elongated in form, with a conical tip, and sometimes also a sharp boring spine at the anterior end. The ectoderm is composed of large cells and is ciliated. One may distinguish also a pair of flame cells (*fl.c*, Fig. 4776), or primitive excretory organs, and a rudimentary **X**-shaped eye spot (*e*). In the interior the cells are smaller and are arranged irregularly about a cavity into which they are set free singly or in groups. These do not become prominent until the miracidium has attained its location in a new host, and this, which it seeks at once on emergence from the egg shell, is almost universally a mollusk. Embedded in the tissue of the mollusk, which is known as the secondary or larval host, the miracidium loses its coating of cilia, its eye spot and its special form becoming a mere irregular sac, now designated as the sporocyst, in which one finds cell masses crowding the cavity and developing into a new generation. In the ordinary case their form is that known as the redia, and when developed they escape from the sporocyst only to enter upon a similar method of reproduction, which gives rise to another new generation. In structure the redia (Fig. 4777) is characterized by an elongate form, a mouth with single oral sucker, a rhabdocœl alimentary canal, two short locomotor protuberances, and an orifice known as the birth opening through which the new brood escapes.

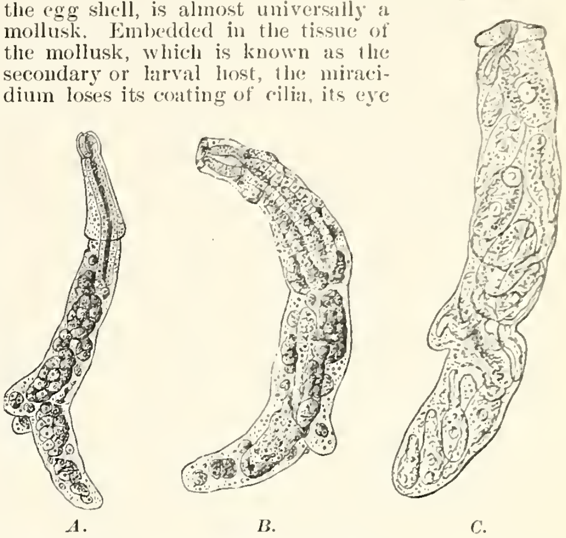
A. *B.* *C.*

FIG. 4777.—Rediæ of *Fasciola hepatica* (L.). × 120. *A*. Young specimen with cell masses just forming; *B*, older individual with young rediæ developing; *C*, form with developing cercariæ. (After Leuckart.)

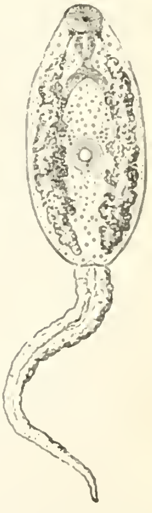
FIG. 4778.—Free Cercaria of *Fasciola hepatica* (L.). Magnified. (After Leuckart.)

This new generation originates as did that in the sporocyst from cells or cell masses set free from the wall of the cavity. The form developing therefrom may be a redia like that which produced it; more often it is still another new form, known as a cercaria, and in some cases the cercaria may even be produced directly from the first generation, the miracidium metamorphosed into a sporocyst or a redia. The form of the full-grown cercaria (Fig. 4778) is sufficiently characteristic to allow of its easy recognition. It is somewhat broader than the redia, possesses a ventral sucker as well as an oral, a triclad alimentary canal, and an active caudal appendage for swimming, though in some forms designated as varieties of this stage this tail may be wanting or modified. The cercaria is in fact the young distome, supplied with an organ of locomotion when some part of the life cycle is to be spent in the open. Now, if not before, the young fluke is ready for the change of hosts which accompanies its attainment of the adult condition. The transfer may be passive or it may be associated with an active migration from the secondary host and a period of existence in the open water before the primary host is reached. Once that the latter is attained, the tail of the cercaria is thrown off and the further development to the adult form is growth, chiefly of the reproductive organs which were present before only in rudimentary form. An encysted stage frequently intervenes. This the cercaria attains by burrowing into the tissue of some animal, or by settling upon the surface of some plant or other object. In the latter case the cyst is formed of the expressed secretion of dermal glands which hardens about the cercaria, which now has cast off its tail. In either event the digestive fluids of the final host are the means of liberating the worm from its cyst to enter upon the final stage of its career.

Great differences in detail are found in different species. The following table, taken from Hertwig, exhibits in synoptic form the principal lines of development. Individual features connected with the species which occur as human parasites may be found under the appropriate headings. The entire process was formerly regarded as the true alternation of a sexual generation, the adult worm, with one or more asexual generations, sporocyst, and redia; but at present the reproduction of the latter is regarded rather as premature parthenogenesis or pædogenesis, and the alternation is called alloiogenesis. Some authors regard it, however, as merely a complicated metamorphosis, which is distributed over several generations. The transportation of the parasite from one host to another may be passive, as when the encysted form is eaten and set free in the alimentary canal of the new host by digestion, or it may be active in that the free swimming larva is engulfed with drinking-water by chance, or bores its way into the body of the water-inhabiting mollusk which it seeks out.

The secondary host is somewhat narrow, so that not only is a direct infection from the adult fluke contrary to all experience, but also the introduction of the adult and the dissemination of the ova in a new region can be followed by the permanent establishment of the parasite only when a suitable larval or secondary host is available. The sheep liver fluke, *Fasciola hepatica*, has thus secured a footing in certain regions of the United States, and has become an important factor in the handling of domestic animals. It remains to be seen whether the human blood fluke, *Schistosoma hæmatobium*, probably introduced from Africa to the southeastern States, and the Asiatic fluke, *Opisthorchis sinensis*, undoubtedly brought to the Pacific coast from the East, will establish themselves similarly to the detriment of the human species.

The encysted cercaria or immature distome occurs rarely in mammals, *e.g.*, the pig, more frequently in amphibians and fishes and generally among invertebrates. The mature trematodes are parasitic only among vertebrates; the ectoparasitic forms inhabiting chiefly the skin or gills of aquatic species, and the endoparasitic forms occurring largely in the alimentary canal, though almost all organs may harbor them at times. Next to the canal, its adnexa, the lungs and liver, are favorite seats of these parasites, but the latter are not wanting in the genito-urinary ducts, where for instance in birds they occur so frequently as to be occasionally enclosed within the egg shell during its formation and are subsequently discovered there. While the flukes usually move freely about in the cavity of the affected organ, they are in some cases more or less completely encysted in its substance. Thus the Asiatic lung fluke, *Paragonimus Westermanii*, is found in pairs in pulmonary cysts, and in rare instances such an association in pairs is connected with the secondarily acquired diœcious condition of the individual species.

Development of the Distomes.

	Simple.		Ordinary.		Complicated.	
First generation	Miracidium Sporocystis	Water Host I. (Mollusk)	Miracidium Sporocystis (possibly also redia).	Water Host I. (Mollusk)	Miracidium Sporocystis	Water. Host I. (Mollusk).
Second generation	Encysted distome Sexually mature distome.	Host I Host II	Cercaria Encysted distome Sexually mature distome.	Water Host II Host III	Redia	Host I. (Mollusk).
Third generation	....	....	....	....	Cercaria Encysted distome Sexually mature distome.	Water. Host II. Host III.

Thus far only thirteen species of fluke have been listed as human parasites; they are as follows:

- Family: Paramphistomidæ.
  - Gastrodiscus hominis.
- Family: Fasciolidæ.
  - Fasciola hepatica.—Species recorded in United States of America.
  - Fasciola angusta.
  - Fasciolopsis Buski.
  - Fasciolopsis Rathouisi.
  - Paragonimus Westermanii.—Species recorded in United States of America.
  - Opisthorchis felineus.
  - Opisthorchis sinensis.—Recorded from man in United States of America.
  - Opisthorchis noverca.
  - Metorchis truncatus.
  - Heterophyes heterophyes.
  - Dicrocœlium lanceatum.—Species recorded in United States of America.
- Family: Schistosomidæ.
  - Schistosoma hæmatobium.—Recorded from man in United States of America.

It thus appears that only five species have ever been found in the United States, and that but two of these have been recorded from the human host. It may be further noted that of these two, one (*Schistosoma hæmatobium*) was certainly acquired in other lands and apparently has not gained a footing in our own, while the same is probably true of the other, leaving for the human host not a single record of trematode infection originating within the limits of the United States.

The earlier stages in the life history, sporocyst and redia, occur only in mollusks, and the selection of the

The effects of parasitism have already been discussed (see *Parasites*); special features as well as means of treatment are treated under individual forms. The human parasites belonging to this group, as already recorded, are too few in number of species to call for a special key as an aid to identification.

Taxonomy.—Valuable recent work by Braun and Looss on the taxonomy of the group makes it possible to give a reasonable system. Only the parts dealing with human parasites will be particularly considered.

Order Heterocotylea.—Ectoparasitic forms with powerfully developed organs of attachment; excretory organs open separately on the dorsum; development direct. Parasitic on body and gills of fishes chiefly. No human parasites.

Order Aspidocotylea.—Endoparasitic Trematoda of simple organization with large ventral organ of attachment; excretory organs open by a single posterior pore; development direct. No human parasites.

Order Malacocotylea.—Trematoda with one or two suckers, or rarely accessory lateral suckers also, for attachment; no chitinous organs of attachment. Intestine usually forked and mouth anterior; mostly hermaphroditic with sexual pore ventral; excretory pore posterior. Always endoparasitic in vertebrata. According to mode of development divisible into two groups:

(*a*) *Metastatica.* Development without alternation of generations, but with two larval forms and change of hosts. No human parasites.

(*b*) *Digenea.* Development complicated by alternation of asexual generations (sporocyst, redia) with sexual generation. One or more changes of host. All human trematode parasites fall in a few families of this very large and varied group, viz.: Paramphistomidæ, Fasciolidæ, Schistosomidæ.

The family of the Paramphistomidæ is characterized by a terminal sucker, dorsal to which the excretory pore is located. The genital pore lies in the midventral line in the anterior third of the body; the pharynx is far forward and ordinarily designated the oral sucker; the intestinal branches are always simple, hermaphroditic. Only one genus is of interest here:

Gastrodiscus Leuckart.—Paramphistomidæ with slender anterior region and large discoidal posterior region, which is concave ventrally. The small terminal sucker lies on the posterior ventral margin of this concavity. Pharynx with two outpocketings.

Various species occur in the alimentary canal of the horse and cattle in Egypt and India; one has been found parasitic in man.

Gastrodiscus hominis (Lewis and McConnell 1876.)—(Syn.: *Amphistomum hominis* Lewis and McConnell 1876.) Body 5–8 mm. long, 3–4 mm. broad, reddish when living. Genital pore at bifurcation of intestinal crura. Eggs oval, 0.150 mm. long, 0.072 mm. broad.

The structure of this species is only imperfectly known. It has been found twice in Assam and India in the cæcum and colon of natives who had died from cholera. Although present in large numbers in these cases Braun regards it as undoubtedly an occasional parasite, the normal host of which is as yet unknown. Giles, however, found it frequently in Assam, and according to Leuckart never more than twelve individuals in a single host, which militates against the idea that it was only an occasional parasite.

The family of the Fasciolidæ is characterized by the presence of oral and ventral suckers, by the genital pore ventral, rarely lateral or terminal; always hermaphroditic, two testes, one germarium, with receptaculum seminis or Laurer's canal, or both, and with paired lateral often highly branched vitellaria.

The majority of human trematode parasites fall within the limits of this very large and highly differentiated family.

Fasciola Linnæus 1758.—Large Fasciolidæ with leaf-shaped body, the anterior end of which has the form of a conical cap or tip, distinctly set off from the posterior region; acetabulum on the boundary of the two regions, large and powerful. Œsophagus short, with pharynx; intestinal crura reaching almost to posterior end near the median line of the body, with short branches on median side and with long, highly dendritic branches on lateral side. Excretory system much branched, reservoir a long median sac. Genital pore in midventral line in front of acetabulum; germarium in front of testes and transverse yolk duct, highly dendritic, as also the testes which are located obliquely behind one another and posterior to transverse yolk duct; uterus in form of a rosette in front of germ glands; vitellaria on sides even to posterior end, well developed. Laurer's canal present, receptaculum seminis wanting. Eggs large, not numerous, developing after deposition. Parasitic in gall ducts of herbivora, more rarely omnivora.

Fasciola hepatica L. 1758.—(Syn.: *Distoma hepaticum* Retzius 1786; *Fasciola humana* Gmelin 1790. *Distomum caviæ* Sonsino 1890; *Cladocœlium hepaticum* Stossich 1892). Body flattened like a leaf (Fig. 4779), reddish-brown in color, 20–30, rarely 35–50 mm. long, 5 or 8–13 mm. broad, with anterior region 4–5 mm. long, and distinctly set off from the posterior; posterior extremity bluntly pointed. Dermal spines over entire body except a small area near the posterior end. Oral sucker terminal, nearly spherical, about 1 mm. in diameter, acetabulum at junction of two regions about 1.6 mm. in diameter, spherical with triangular aperture. Pharyngeal bulb covering nearly entire œsophagus, intestinal crura, with numerous dendritic branches directed laterad; vitellaria, lateral, dendritic, both dorsal and ventral of intestine. Germarium and testes both dendritic, former anterior, latter posterior to transverse yolk duct and side by side. Eggs oval, 0.130–0.145 mm. long by 0.07–0.09 mm. broad, deposited before commencement of cleavage.

This species is parasitic in the biliary ducts of sheep especially, but it also occurs in many other ruminants, cattle, goat, horse, ass, deer, antelope, camel, as well as in the kangaroo, squirrel, beaver, rabbit, guinea-pig, and man.

Life History.—The complicated development of this form has been elucidated chiefly by the researches of Leuckart and Thomas. The eggs must remain some weeks in water at the ordinary temperature to complete the development of the miracidium, which on being set free seeks out a small snail (*Limnæa truncatula* Müll. = *L. minuta* Drap.) that is commonly found in small pools or on partially flooded meadows.

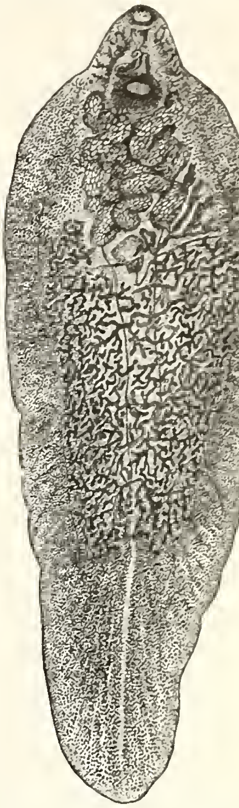

Fig. 4779.—*Fasciola hepatica* (L.). American Specimen from Cattle. Magnified. (After Stiles.)

The miracidium (Fig. 4776) attaches itself to some fleshy region of the snail, throws off its ciliary coating and then penetrates to the snail's liver, where it becomes a mere sac filled with masses of developing germ cells. This sac, known as the sporocyst, produces rediæ, which remain in the same host, and sometimes give rise to a second generation of rediæ (Fig. 4777, *A*, *B*). The cercariæ (Fig. 4777, *C*, and Fig. 4778), which are produced by rediæ sooner or later, make their way out of the snail and encyst on blades of grass, with which they attain the final host in its food. The young distome set free in the stomach is small, transparent, without separate regions of the body, and with only rudiments of the reproductive organs. It makes its way far up into the gall ducts of the liver and there attains its maximum size. The life of the adult lasts probably not more than a year, but infection of the final host takes place most commonly in the early fall or late summer. In the spring the eggs are most abundantly distributed over the meadows, with the excrement of the sheep. Lutz found that in the Hawaiian Islands *Limnæa oahuensis* and *L. rubella* served as intermediate hosts. None of these species occur in the United States, and the species which actually serves as larval host is as yet unknown.

The common liver fluke is distributed over nearly the whole of Europe; it also occurs in North and South America and Australia, where it has been introduced in domestic animals. Records of its occurrence in Africa and Asia are undoubtedly due, in part at least, to confusion with closely related species, and must be verified before they can be accepted as final.

Pathology.—Known since the middle of the sixteenth century, the common liver fluke was first positively identified as a human parasite by Pallas in 1760, although earlier reports of Malphighi and others probably concern this species. Between twenty and thirty well-established cases are on record; they have been compiled and discussed by Leuckart, Blanchard, and Moniez. All degrees of infection are represented, from such as were so slight as to have been discovered by accident to such as were the direct cause of death. In the bile ducts the flukes have only rarely evoked serious symptoms, though in two or three cases fatal termination was due to obduction of the ductus hepaticus s. choledochus by one of these flukes. In the majority of cases the parasite produced no noticeable symptoms, evidently due to the presence of only a small number of individuals, and it is possible that infection is more general than heretofore believed. At any rate Kratter proclaims it to be frequent in Dalmatia, and Perroncito found distome eggs frequently in fæcal examinations among laborers at the St. Gothard tunnel. Even in severer cases the symptoms are general, indicating only some affection of the liver. Thus pain in that organ, swelling and icterus have been mentioned by different observers. In the majority of cases, also, the parasite has not been found in its normal seat, the liver, but as an erratic in the lungs, in blood-vessels, in subcutaneous tumors, and elsewhere. This is not strange in the light of Railliet's demonstration that the liver fluke subsists on blood; thus young flukes especially may make their way into the circulatory system and be carried by the blood current into any part of the body.

Such occurrences of erratic individuals give some basis for the interpretation of other doubtful organisms as also belonging to this species, and many authors regard the *Hexathyridium venarum*, reported by Treutler in 1793, from the tibial vein of a young man which ruptured while the patient was bathing, as an erratic specimen of *Fasciola hepatica*. Leuckart, however, says there is more reason to regard it as a free living planarian, which did not actually come from the vein, but was obtained accidentally from the water.

These cases of parasitism of *Fasciola hepatica* in man have been reported largely in European countries, the only one outside being from Australia. The record of Chabert in 1852, that this species occurred in Boston in company with *Tænia*, rests upon an erroneous view regarding the isolated segments of the tapeworm, as Leuckart and Cobbold have clearly shown. Nevertheless in those parts of this country where *Fasciola hepatica* is common, cases of human infection are likely to occur. This takes place supposedly through the consumption of cress, lettuce, and other uncooked plants which have been grown in low, damp regions where infected snails were present, and where consequently the liberated cercariæ had opportunity to encyst upon the leaves. The evident infrequency of such an occurrence coincides with the usually mild infection in man as compared with the domesticated animals.

Associated with the light infection and also with its infrequency is the absence of any definite symptoms in the human host which denote the presence of the parasite. As already explained, the infection usually becomes known only by chance; but even were it determined by accidental discovery of the eggs in fæcal examinations, no special means could be suggested to bring about the evacuation of the parasite, which lies deep in the ducts of the liver, and is held against retrograde movements by the thick-set, retrorse spines that cover nearly the entire body. So far as can be determined the life of the adult lasts not more than about a year. Care in the use of uncooked plants should be exercised in all regions where these flukes are abundant.

Agamodistomum ophthalmobium (Diesing 1850).—(Syn.: *D. oculi humani* Gescheidt 1833; [?] *Monostomum lentis* Gescheidt 1833; *Distomum ophthalmobium* Diesing 1850.) Two cases of some interest may be noted here in which the parasites are too poorly known to allow of exact identification. In one case four immature distomes were removed from the eye of a five months' child with lenticular cataract with partial opacity of the capsule. The other case was that of an elderly woman from whose eye eight so-called monostomes were removed from the lens substance. The descriptions do not enable one to determine the species or to assert the identity of the forms. They were undoubtedly erratic parasites, and it seems highly probable that in the former case at least the parasite was the young form of one of the liver flukes of man. Several authors regard them as very young lancet flukes (*Dicrocœlium lanceatum*) which had strayed into this unusual location. There is every ground for believing them to be pathogenic, as are other species in the eyes of other vertebrates (*e.g.*, fish), and a repetition of the occurrence on the part of the erratic young of the same or other species may be confidently predicted. (For full data on these cases compare Stiles 1902.)

Fasciola angusta (Railliet 1895).—(Syn: *F. hepatica* var. *angusta* Railliet 1895). Body flat, linguiform, with sides nearly parallel and slenderer than *F. hepatica*. Length, 26–38 mm.; breadth, 6–8 mm. Anterior region short. Posterior end broadly rounded. Acetabulum large, prominent, only 2 mm. from anterior tip of body. Eggs oval, 0.143 to 0.151 mm. by 0.082 to 0.088 mm.

Railliet described this form from the liver of cattle slaughtered in Senegal, and at the same time called attention to a case recorded by Gouvea, a physician in Rio Janeiro. The patient, a French marine officer, suffered from fever, cough, and blood spitting. The only pulmonary defect demonstrable was a sharply defined spot at the base of the left lung. Some twenty days later he coughed up a fluke, which probably belonged to this species, and was acquired during a residence in Senegambia. Blanchard regards it, however, as *F. gigantica* Cobb. mentioned below.

The case demonstrates also the susceptibility of man to other species of the genus Fasciola as well as to that ordinarily known, and renders it advisable to make brief mention here of the other species of this genus which are likely to be encountered in various regions.

Very closely related to the last species are *Fasciola ægyptiaca* Looss, which occurs in the domesticated herbivora of Egypt, and *F. gigantica* Cobbold, which was originally described from the liver of the giraffe, but which, according to Blanchard, occurs in the cattle of Senegambia and other regions in Africa. Probably these species may be introduced under favorable chances into the human host as well as the related species already described.

More important for American physicians is the allied native species which is so widely distributed on this continent. Although it has not yet been reported as a human parasite, the probability of its occurrence as such is sufficiently immediate to call for its description here.

Fasciola magna (Bassi 1875) Stiles 1894.—(Syn.: *Distomum magnum* Bassi 1875; *F. carnosa* Hassall 1891; *F. americana* Hassall 1891; *D. texanicum* Francis 1891; *D. crassum* [in part] Leidy 1891; *Cladocœlium giganteum* [in part] Stossich 1892.) Body flesh-colored when alive, broad, thick; much larger and thicker than *F. hepatica*; length, 23–100 mm.; breadth, 11–26 mm.; thickness, 2–4.5 mm. The conical anterior part is not distinctly set off from the posterior. The posterior end is bluntly rounded, and margin more convex. In general the structure is very similar to *F. hepatica*, except that the œsophagus is longer, one-and-a-half to three times as long as the pharynx, the intestines more branched, and the yolk glands confined to the ventral side of the intestine; eggs oval, 0.109–0.168 mm. long by 0.075–0.096 mm. wide.

This fluke is found in cysts in the liver and lungs of cattle and of several species of deer, and is very widely distributed, occurring on the authority of various persons in Texas, Arkansas, California, Iowa, Illinois, New York (Adirondacks), and Italy. It is probably present in most parts of this country. In importance it stands hardly second to *F. hepatica*, but of its life history nothing is definitely known. Its close relationship to other species which have been reported occasionally from the human host in Europe indicates that this species also may adopt the same rôle here when circumstances favor.

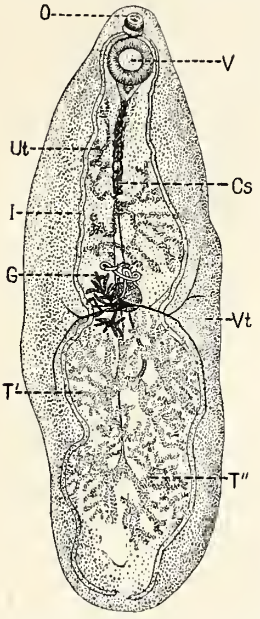

FIG. 4780.—*Fasciolopsis Buski* (Lank.). *Cs*, Cirrus sac; other abbreviations as before. × 3. (After Odhner.)

Fasciolopsis Looss.—Fasciolinæ without distinct anterior and posterior regions. Cuticula smooth. Acetabulum powerfully developed with cavity extended posteriad as sacculate invagination and much larger than oral sucker. Intestinal crura simple, slender, wavy but without evaginations. Testes dendritic, with branches growing smaller toward distal ends. Cirrus pouch very long, cylindrical, containing spiral tubular seminal vesicle with peculiar cæcal appendage. Cirrus closely covered with fine spines. In alimentary canal of mammals.

Fasciolopsis Buski (Lankester 1857).—(Syn.: *Distomum Buski* Lank. 1857; *Distoma crassum* Busk 1859, nec v. Sieb. 1836). Length, 24–37 mm., average about 30; breadth, 5.5–12 mm., average, 9 mm.; greatest thickness, 1.5 mm.; body (Fig. 4780) flattened, linguiform, anterior region tapering, but not sharply marked off from posterior body. Anterior sucker 0.5 mm. in diameter, acetabulum separated by not more than its diameter (1.6–2 mm.) from anterior end, with deep triangular lumen. Pharynx large, powerful; prepharynx present; œsophagus very short; intestinal crura slender, extending to extreme posterior end in three shallow curves. Testes dendritic one behind the other in median field, and both posterior to transverse yolk duct; cirrus sac median, cylindrical, much elongated, enclosing long spiral seminal vesicle with lateral elongate cæcal appendage. Germarium small, dendritic, anterior to testes, and to transverse yolk duct; Laurer's canal present, receptaculum seminis wanting; uterus in scanty irregular open coils, anterior to ovary; yolk glands lateral with numerous very small acini extending length of body; genital pore immediately at anterior margin of acetabulum, cirrus covered with many fine spines; eggs numerous, 0.12–0.126 mm. in length, 0.077 mm. in breadth; similar to those of *Fasciola hepatica*.

Eight positive and several uncertain cases of the occurrence of this species are on record. They are all from southern or eastern Asia and all concern the human host. The parasite occurs in the duodenum according to Busk, and the symptoms of Cobbold's and Olhner's cases pointed unmistakably to this as an intestinal parasite. No facts on the life history are recorded as yet. In 1891 Leidy reported as belonging to this species specimens received from New York, Arkansas, and Texas, where they were collected from the liver of a doe in the first case and from cattle in the other two instances. The species he had under observation, however, was actually *Fasciola magna*, and there is no evidence that *Fasciolopsis Buski* has been found on this continent, although its occasional introduction by the Chinese is not a remote contingency in view of the known facts regarding other species (*cf. Paragonimus Westermanii* and *Opisthorchis sinensis*).

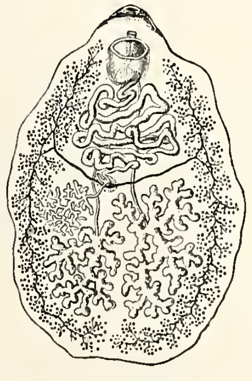

FIG. 4781.—*Fasciolopsis Rathouisi* (Poirier). × 2. (From Leuckart, after Poirier.)

Fasciolopsis Rathouisi (Poirier 1887).—(Syn.: *Distomum Rathouisi* Poirier 1887.) Length 25 mm., breadth 16 mm., oval, with indistinctly marked anterior region (Fig. 7481). Cuticula smooth. Oral sucker 1.5 mm., ventral 2 mm. in diameter. Intestinal crura unbranched; germ gland dendritic, posterior to transverse yolk duct; vitellaria lateral, not joined posteriad; uterus in centre of anterior half of body; genital pore just in front of acetabulum. Eggs 0.150 by 0.08 mm.

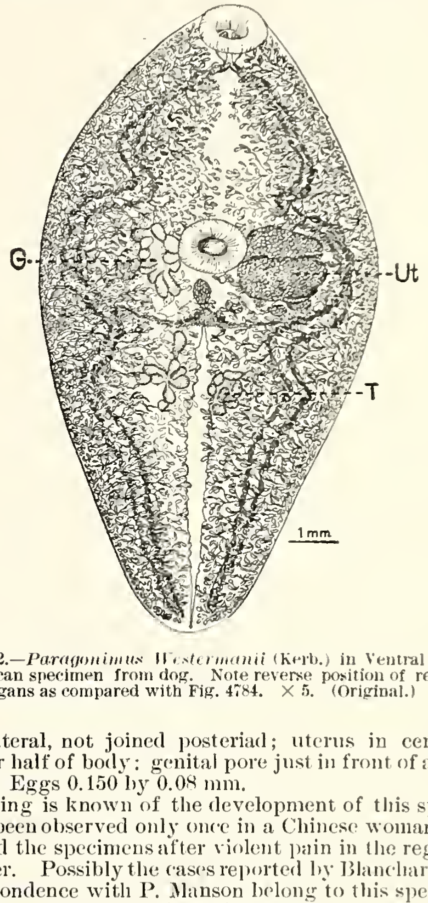

FIG. 4782.—*Paragonimus Westermanii* (Kerb.) in Ventral Aspect. American specimen from dog. Note reverse position of reproductive organs as compared with Fig. 4784. × 5. (Original.)

Nothing is known of the development of this species. It has been observed only once in a Chinese woman, who vomited the specimens after violent pain in the region of the liver. Possibly the cases reported by Blanchard from correspondence with P. Manson belong to this species.

Paragonimus Braun 1899.—Body thick, oval, or spindle-shaped, and nearly circular in transsection. Cuticula spinous. Acetabulum near centre of body. Alimentary canal with prominent pharynx, very short œsophagus, and intestinal crura extending in irregular zigzag to posterior end. Excretory bladder large, extending nearly to pharynx. Genital pore lateral near acetabulum. Special copulatory organs wanting. Testes dendritic, right and left in posterior region. Germarium also dendritic, anterior to left testis. Receptaculum seminis lacking. Laurer's canal present. Vitellaria extensive, on side of body almost the entire length and dorsal also almost to median line. Uterus scantily developed as coil lateral to and near acetabulum. Eggs large. Usually by pairs in cysts in lungs of mammals.

Paragonimus Westermanii (Kerbert 1878).—(Syn.: *Distoma Westermanii* Kerbert 1878; *D. Ringeri* Cobbold 1880; *D. pulmonale* Baelz 1883; *D. pulmonis* K. S. and Y. 1881; *Mesogonimus Westermanni* Railliet 1890.) Length 8–16 or even 20 mm., breadth 4–8 mm., body thick and plump, posterior end more pointed, ventral surface more flattened (Fig. 7482); color, deep red or reddish-brown when alive, or dark gray in alcoholic material, with conspicuous black dendritic acini of the yolk gland along the side. Cuticula spinous; oral sucker 0.53–0.75 mm. (Leuckart), or 0.86–1.2, or even 1.4 mm. (Ward). Acetabulum 0.6–0.75 mm. (Leuckart), 0.75–1.02 mm. (Ward); slightly larger than oral sucker, situated anterior to middle of body; œsophagus short, intestinal cæca wavy, with irregular outline, extending to posterior end of body. Germarium branched, posterior to acetabulum, lateral, opposite the lobate shell gland, which lies directly in front of the condensed uterus. Yolk glands highly developed, extending from anterior to posterior end, absent only over narrow median field. Testes branched, lateral, in posterior portion of body; cirrus and cirrus pouch wanting genital pore, near posterior margin of acetabulum, either median, right, or left; eggs oval, 0.08–0.1 by 0.05 mm. (Leuckart) or 0.096–0.118 by 0.048–0.055 mm. (Ward) (Fig. 4783).

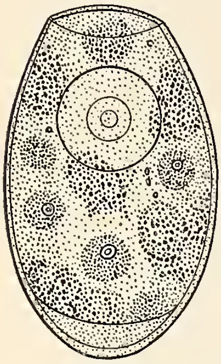

FIG. 4783.—Egg of *Paragonimus Westermanii* (Kerb.). Magnified 500. (After Katsurada.)

The oval ciliated embryo develops within the egg some time after the latter has been discharged with sputum from the host. Further life history unknown.

This parasite has been found in the tiger, cat, dog, and hog as well as in man. It appears from the studies of Ward and Stiles that differences in size are noticeable between the Asiatic (Fig. 4784) and American (Fig. 4782) forms. These differences are noted in the specific description given above. Further study may show them to be distinct species. The different arrangement of the sexual organs may represent the condition of sexual amphitypy noted above.

Distribution.—The parasite is known from Japan, China, Corea, and Formosa, where according to good authorities fifteen per cent. of the entire population is infected. In this country it has been reported from Michigan and Ohio by Ward, and from Kentucky and West Virginia by Stiles, according to whose accounts it seems to be common in hogs of the infested district. Thus far it has not been reported from a human host in the United States. Stiles has made an exhaustive study of the species, but is unable in spite of the recorded differences in size to differentiate specifically the American and Asiatic forms. Even should they prove to be distinct, however, possible danger to man would not be eliminated since the Asiatic form has been found in cat, dog, and hog as well as man, and the American form, which has thus far been reported only from the cat, dog, and hog, may confidently be expected to recur in man in the infected district. Until the announcement by Stiles of the existence of an extensive infection among hogs, it was not clear that the species had actually established itself in the United States, as the two cases in cat and dog which Ward reported might have been introduced from Asia after infection. Now that a large number of cases is known from this country, the endemic character of the species cannot be doubted. It is of the greatest importance that the distribution be more precisely established, and the life history worked out to show the points of danger for the infection of man and the precautions which must be taken to guard against it.

Pathology.—The disease was first reported from man in 1880 by Manson, who called it parasitical hæmoptysis and later endemic hæmoptysis. The term pulmonary distomatosis has also been used. From the cases thus far on record in detail, it is apparently much more prevalent in males than in females, and seventy-five per cent. of these cases occurred among farmers. Both of these facts undoubtedly point to factors in the life history which make infection of such persons easier rather than to any inherent suscepibility; in fact Yamagiwa states that strong persons are more susceptible than weak, but this is evidently because they are more given to outdoor occupations, and hence more open to infection.

Ordinarily the worms are found in the lungs, where they lie in tumors about the roots and along the dorsal border directly under the pleura, sometimes surrounded by a capsule or again burrowing into the lung tissue. The worms occur in man usually one, but in other hosts two, in each cyst, although instances are not rare where one or several have been taken from a cyst, and some cysts contain eggs but no adult worm. The cysts contain not only the worms, but also masses of eggs, and Charcot's crystals, while cholesterin crystals are also occasionally present. The eggs and crystals reach the exterior in masses of mucus and blood through fine openings which communicate with the bronchi. The number of eggs discharged in the course of a single twenty-four hours may be enormous, and was estimated in case of one patient who had suffered thirteen years from the disease as not less than twelve thousand daily.

Yamagiwa has also found in the brain cysts containing the parasites and eggs or simply the eggs. Foci of these eggs and small blood-vessels filled with them occurred in the cortical substance of occipital and parietal lobes; these were associated with giant cells and surrounded by proliferating connective-tissue and round-cell infiltration. The lungs of the same host showed characteristic lesions due to these flukes. so that Yamagiwa concluded that this was the source of the egg emboli found in the brain. These cases, of which several are already on record, are characterized by epileptic attacks (Jacksonian or cortical epilepsy).

Yamagiwa has also found cysts containing the eggs of this species in the liver, causing or associated with cirrhosis of that organ, as well as in the diaphragm, peritoneum, mesentery, and walls of the intestine.

Symptomatology.—When in the lungs, its common abiding place, the distome gives rise to periodic hæmoptysis and chronic cough, with rusty, mucoid expectoration; spitting of blood is common but not constant. The condition of the patient remains good, and almost no abnormal sounds can be detected by percussion of the chest. Yamagiwa says that the general appearance of the expectoration is identical with tuberculosis, and that the disease was formerly diagnosed as such in Japan. The presence in the sputa of the eggs already described makes a positive diagnosis by microscopic examination easy. Accidental rupture of a large blood-vessel by the destruction of lung tissue, and in severe cases general anæmia, are the dangers to be feared.

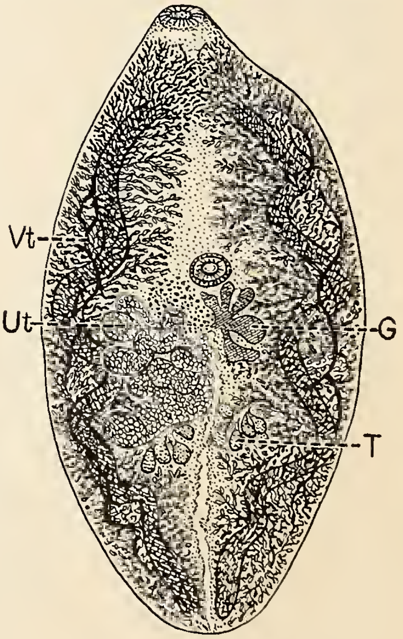

FIG. 4784.—*Paragonimus Westermanii* (Kerb.) in Ventral Aspect. Japanese specimen from human lung. × 7. (After Katsurada.)

Removal from an infected district is followed usually by complete recovery.

In absence of any knowledge regarding the life history the mode of infection is entirely in the dark, and equally also the means of prevention. On general grounds drinking-water has been suspected; more suspicious are all uncooked plant foods, and especially such as are grown in moist places. In the light of present knowledge little weight can be laid upon the ideas of certain Japanese that fish, eggs, and meat are responsible for the transference of the parasite to the human host.

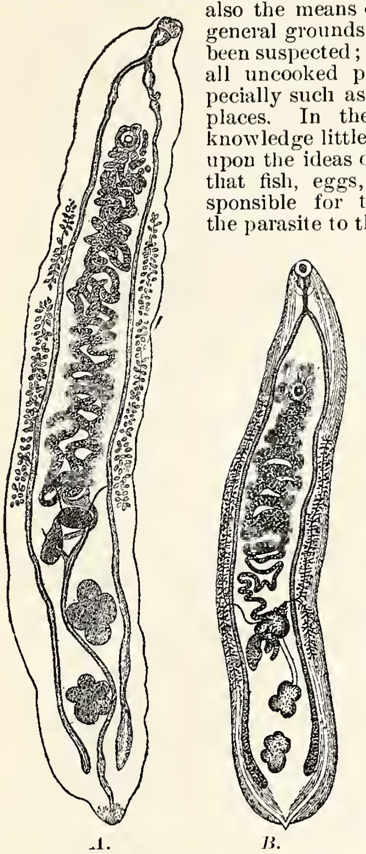

Fig. 4785.—*Opisthorchis felineus* (Riv.). *A*, Elongated Specimen from Liver of Cat. (After Braun.) *B*, "Distomum sibiricum" from liver of man. (From Braun, after Winogradoff.) Magnified.

Opisthorchis R. Blanchard 1895.—Body flat, elongated, broad posteriorly, but tapering toward the anterior end. Cuticula without spines Testes lobed or even branching, located one obliquely behind the other in posterior region. Genital pore just in front of acetabulum; no special copulatory organs. Receptaculum seminis large, Laurer's canal present, germarium anterior to testes. Uterine coils anterior to germarium and within intestinal crura. Vitellaria lateral, never anterior to acetabulum. Excretory bladder Y-shaped, the long unpaired stem curved like an S between the testes.

Opisthorchis felineus (Rivolta 1885.)—(Syn.: *Distoma conus* Gurlt 1831, nec Creplin 1825; *D. lanceolatum* v. Siebold 1836, v. Tright 1889, nec Mehlis 1825; *D. sibiricum* Winogradoff 1892; *D. tenuicolle* Mühling 1896.)

Body much flattened, with sides parallel save that the region anterior to the acetabulum is conical and very changeable in form when alive. Posterior end often slightly pointed. Color faint reddish-brown or yellow; when alive, transparent. Length 8-11 mm., breadth 1.5-2 mm. Suckers separated by only one-fifth to one-sixth of the length, nearly equal in size (0.23-0.25 mm.). Œsophagus very short, intestinal crura reaching nearly to posterior end. Excretory bladder forking anterior to testes. Anterior testis four-lobed, posterior five-lobed. Germarium median, transverse, smaller than the pyriform seminal receptacle just behind it. Uterus entirely within intestinal crura. Vitellaria, in the broad lateral fields, composed of seven to eight distinctly separated groups of follicles, all anterior to ovary. Genital pore immediately preacetabular. Eggs oval with distinct lid at pointed pole, 0.030 by 0.011 mm.

This much confused species has been carefully studied by Braun. It inhabits the gall ducts and gall bladder of the cat, dog, fox, glutton, and man. Of the life history little is known. The eggs when laid contain a ciliated miracidium which, according to Braun, will not hatch out in water, although in Winogradoff's experiments they are said to have done so. Further knowledge on the development is lacking.

Distribution.—Germany, France, Italy, Holland, Scandinavia, Hungary, Russia, Siberia, and if correctly reported Japan also, are the countries in which the species has been found. It is apparently most abundant on the shores of the Baltic, and the general correspondence of its distribution with that of the human tapeworm, *Dibothriocephalus latus*, is worthy of note.

Pathology.—In 1892 Winogradoff found in post-mortems at Tomsk (Siberia) cases of what he thought to be a new human parasite. This he described as *Distoma sibiricum* (Fig. 4785, *B*), but it is probably identical with the species from the cat studied by Braun (Fig. 4785, *A*). Fifteen cases have been reported from Siberia, Russia, and East Prussia. In Tomsk it is the most common human parasite and in East Prussia is also common. Although in no case was a fatal termination attributable to this parasite, yet pathological changes in the liver were noted, such as dilatation of the gall ducts with inflammation and thickening of the walls, and atrophy of hepatic tissue. In recently infected cases the liver was enlarged; in older ones, on the contrary, smaller than normal. Ascites was noted in three cases, icterus in five. Askanazy found hepatic carcinoma in both of the cases he studied closely, and noted that it occurred in the region most visited by the parasites. He was accordingly inclined to place these facts in causal relation since the changes incited by the flukes consisted in manifold, even dendritic, proliferation of the mucosa into the likewise proliferating connective tissue. In both these cases there were over a hundred parasites found in the infected organ, and they were met with also in the pancreatic duct and in the intestine. In other cases on record the number of parasites found varied from a few to several hundred.

In view of the frequent confusion of this species with *Dicrocœlium lanceatum* it is possible that some records included under the latter actually concern the former species. It has been conjectured with good reason that man acquires this species, like *Dibothriocephalus latus*, through the consumption of uncooked fish in which the young distome is encysted, and it is striking that in all of Askanazy's cases in East Prussia both these parasites occurred together. That author, however, was unsuccessful in the effort to infect experimentally with this parasite, or to discover its immature stage.

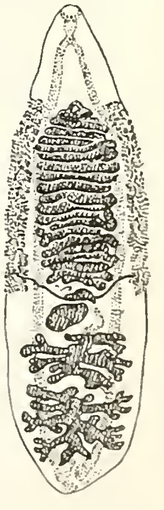

Fig. 4786.—*Opisthorchis sinensis* (Cobb.). Contracted specimen from man in Japan. × 6. (After Katsurada.)

A closely related American species is one which I originally described as a variety of *O. felineus*, but now believe to be entirely distinct. This is *O. pseudofelineus* Ward 1900 (Fig. 4772), which is a frequent parasite of the cat in some parts of the country, and has been found in the dog and coyote also. The intermediate host is unknown, but many facts point to some fish. Its transfer to the human host might be brought about by chance, or as in the case of the closely related species of the Old World. It occurs here in much the same hosts save man, and consequently would probably be able to maintain itself in the latter host also.

A small spiny distome which Winogradoff found in man in one instance, and which he regarded as the immature form of *O. felineus*, has been tentatively identified by Braun as *Metorchis truncatus* (Rudolphi 1819). This species is a normal parasite of the cat and had probably reached the human host in the same manner as *Opisthorchis felineus*, with which it is moreover often associated in the cat. As this form is parasitic not only in the cat, dog, fox, and glutton, but also in two species of seal, still further evidence is furnished of the transmission of this and the preceding species through fish food.

Opisthorchis sinensis (Cobbold 1875).—(Syn.: *Distoma* *sinense* Cobbold 1875; *D. spathulatum* Leuckhart 1876, nec Rudolphi 1819; *D. hepatis endemicum* s. *perniciosum* Baelz 1883; *D. hepatis innocuum* Baelz 1883; *D. japonicum* R. Blanchard 1886; *D. endemicum* Ijima 1886.) Length 9–15 or even 18 mm.; breadth 2.4–4 mm.*

Body translucent, slightly tinted with yellow or red; form elongate, attenuated toward anterior end, bluntly pointed at posterior (Fig. 4786). Oral sucker larger than ventral and separated from it by one-fourth the entire length. Testes deeply lobed or dendritic, one behind the other in posterior end and overlapping the intestinal crura; anterior to them the prominent receptaculum seminis and then the germarium, faintly lobed, in the median line. Vitellaria lateral, extending from the acetabulum to germarium or slightly further posteriad. Uterus in transverse coils between acetabulum and germarium, but within intestinal crura. Genital pore at anterior margin of acetabulum. Eggs, from fæces 0.027–0.030 mm. long, and 0.015–0.0175 mm. broad; exceptionally 0.035 by 0.019 mm., or at the other extreme 0.02 by 0.0157 mm.; miracidium developed before extrusion from uterus. Parasitic in the cat, dog, and man.

It has been found abundantly in Japan, but occurs also in Corea, Formosa, Tonquin, China, India, and Mauritius. A single case has been reported from New York City by Biggs; the host was a Chinaman. Recently White has found eighteen cases of infection with this parasite (Fig. 4787) in San Francisco. All were detected at necropsies, and of the cases sixteen were pest infected, one had beriberi, and one valvular heart disease. White was inclined to believe that some of the cases were infected in California, though no evidence has yet been published to show that the species has actually established itself on this continent.

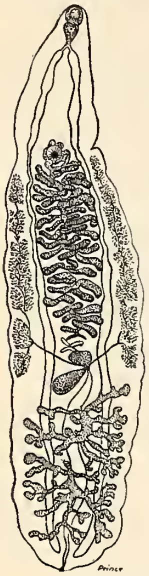

FIG. 4787.—*Opisthorchis sinensis* (Cobb.). Moderately extended specimen from man in California. Case of White. Magnified. (Original.)

In Japan the population is widely infected; the parasite is sporadic in some regions, but in other localities in several provinces it is endemic; in some districts of the province Okayama, according to Katsurada, from fifty-six to sixty-seven per cent. of those subjected to fæcal examination were infected. Of the development the ciliated embryo alone is known. This is formed when the eggs (Fig. 4788) are passed in the fæces of the host; but, according to Ijima, it does not desert the shell spontaneously, even after five months. The intermediate host is probably a mollusk, and the rice fields, which are often fertilized by human excrement, are centres of infection. The mode of transmission can only be conjectured.

The parasite occurs either in the gall ducts and gall bladder or in the pancreatic ducts. It is present also in the duodenum and rarely in the stomach and spleen. The pathological changes are of a mechanical type, and apparently generally proportionate to the duration of the disease and to the number of worms present, which may reach ten thousand or more in a single host. In cases of severe infection the death of the patient follows; this occurs in about fourteen per cent. of the sick. Two hundred and twenty fatal cases were recorded in twelve years in the province of Okayama. Like other species, this parasite has been found outside the liver in pus of a phlegmon on the right side of the abdomen, and in a second case on the diaphragm.

Pathology.—The hepatic lesions produced by flukes were first accurately determined by Schaper for *Fasciola hepatica* in cattle and sheep, and subsequently confirmed by Katsurada and Blanchard, both of whom studied the changes in the human liver produced by *Opisthorchis sinensis.* The results show essential similarity in all cases studied. The lesions are of two sorts; the first, due to the occlusion of the biliary ducts by the parasites, is largely mechanical, and consists in stasis of the bile and dilatation of the ducts with resulting effects on general nutrition. At the same time the resulting inflammation leads to desquamative catarrh accompanied by thickening of the mucosa and glandular hyperplasia. There is also a proliferation of the connective tissue together with increase in blood capillaries and cellular infiltration, which aids in the reduction of liver tissue and in the obliteration of bile ducts. Atrophy of the parenchyma and granular degeneration bring about the destruction of the capillaries, and ultimately the transformation of a larger or smaller portion of the liver into a mass of cicatricial tissue containing only metamorphosed gall ducts.

The effects upon the circulatory system are primarily mechanical in the injuries to capillaries producing multiple hemorrhages, and where these discharge through gall ducts resulting in anæmia. The inflammation produced by the movements of the flukes affects the walls of the blood-vessels and renders it possible for the flukes to gain entrance to the system, and thus be carried to various parts of the body. The growth of connective tissue serves ultimately to compress branches of the portal system, or even partially to obliterate them, and the circulatory stasis is followed by ascites or œdema. Enlargement of the spleen, pathological changes in the pancreas, when that organ also becomes infected, and chronic gastro-intestinal catarrh have been recorded. In fluke disease among animals it has also been noted that the blood is poor in hæmoglobin and subnormal in number of corpuscles.

Opisthorchis noverca Braun 1902.—(Syn.: *Distoma conjunctum* Lewis and Cunningham 1872, McConnell 1876, nec Cobbold 1859.) Body lancet-shaped, spinous, 9.5–12.7 mm. long by 2.5 mm. broad. Suckers close together, the oral being larger than the ventral. Pharynx spherical, intestinal crura extending far posteriad. Genital pore immediately in front of acetabulum; testes round or only slightly lobed, at limit of posterior third of body and nearly opposite. Germarium slightly lobed, in front of bifurcation of the **Y**-shaped excretory reservoir. Uterus in loops through central area from germarium to genital pore. Vitellaria lateral, from testes anteriad nearly to acetabulum. No cirrus sac. Eggs oval, 0.034 by 0.021 mm.

Found in a necropsy in Calcutta in large numbers in the gall ducts of two Mohammedans by McConnell. Similar parasites were discovered a few years earlier by Lewis and Cunningham in the liver of street dogs in the same city. No doubt these forms were both the same species, but Braun has shown clearly that they cannot be the species which Cobbold had found earlier in the liver of an American fox that died in London, and to which the discoverers had assigned them.

FIG. 4788.—Egg of *Opisthorchis sinensis* (Cobb.) ×500. (After Katsurada.)

Heterophyes Cobbold 1866.—Body without distinct separation into anterior and posterior region. Oral sucker without crown of spines. Pharynx close to oral sucker, intestinal crura extend to posterior end of body. Genital orifice lateral, near acetabulum, surrounded by prominent muscular genital sucker with circle of branched chitinous spines. Vitellaria near posterior margin, scantily developed.

Heterophyes heterophyes (v. Siebold 1852).—(Syn.: *Distomum heterophyes* v. Siebold 1852; *Mesogonimus heterophyes* Railliet 1890; *Cœnogonimus heterophyes* Looss 1900; *Cotylogonimus heterophyes* Lühe 1900.) Length 1–1.7 mm., breadth 0.3–0.6 mm. Limit between anterior mobile and posterior regions often indistinct in alcoholic material (Fig. 4789). Acetabulum very powerful, thick-walled, about two and one-half times and genital sucker about one and one-half times as large as oral sucker; average diameter of oral sucker 0.09 mm., of ventral sucker 0.23 mm., of genital sucker 0.15 mm. Intestinal crura thin, terminating posteriorly at excretory bladder. Lateral acini of vitellaria outside intestinal crura, sometimes even extending on to ventral surface. Testes near posterior end, just anterior to tips of intestinal crura. Germarium median in posterior region, uterus covering nearly entire posterior end. Eggs light brown, thick-shelled, 0.03 by 0.017 mm.; ciliated miracidium fully developed when egg is deposited (Fig. 4790). Parasitic in dog, cat, fox (?), and man in Egypt. A single record of its presence in dogs in Japan needs confirmation. The species was discovered in 1851 by Bilharz in the intestine at the necropsy of a boy in Cairo. The belief that the species was rare in man has been dispelled by the studies of Looss, who finds it rather common; on account of its diminutive size, however, it is easily overlooked. This author has also recently differentiated some closely related species which have been found in other hosts and listed heretofore under the same name. Its seat is the middle third of the duodenum, and it is often found by the hundreds. It usually moves about freely in the chyle, but may remain attached to the wall or concealed in the folds of the mucosa. The parasite feeds on the contents of the intestine, and neither blood corpuscles nor epithelial cells could be found in its alimentary canal. This accounts for its apparently harmless character even when present in large numbers. In spite of the prominent spines on the skin Looss was unable to recognize in any case alterations in the mucosa of the host, which could be attributed to the work or presence of the parasite. According to Looss also the parasite affects particularly the country population and is wanting in those who live in the cities as well as in Europeans.

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* According to previous reports the worm varies widely in size with hosts and number of individuals present. Even yet it may be questioned whether two or more species are not confused under this name by different observers.

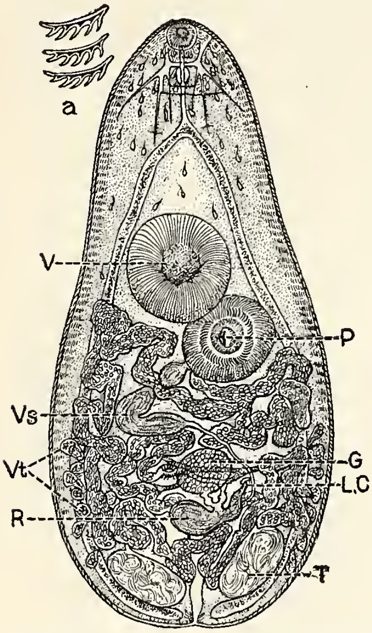

FIG. 4789.—*Heterophyes heterophyes* (v. Sieb.) in Ventral Aspect. *a*, Cuticular spines from margin of genital sucker, *P*. Other letters as before. × 42. (After Looss.)

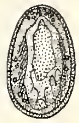

FIG. 4790.—Egg of *Heterophyes heterophyes*. × 500. (After Looss.)

Dicrocœlium Dujardin.—Body delicate, semitranslucent; form elongate, foliate, tapering toward both ends, with smooth cuticula; oral and ventral suckers separated by less than one-fourth total length. Pharynx small; œsophagus short; intestinal crura long but not extending to posterior end. Cirrus sac anterior to acetabulum, enclosing coiled seminal vesicle and long slender cirrus. Genital pore between pharynx and fork of intestine. Testes compact, forming with the smaller compact germarium a median series directly posterior to acetabulum. Laurer's canal and receptaculum seminis present. Uterus in transverse coils, filling region posterior to germarium. Vitellaria lateral to intestinal crura, only moderately developed. Eggs dark brown, numerous.

Dicrocœlium lanceatum Stiles and Hassall 1896.—(Syn.: *Fasciola lanceolata* Rudolphi 1803, nec Schrank 1790; *Distomum lanceolatum* Mehlis 1825; *Dicrocœlium lanceolatum* Dujardin 1845.) Length 4, usually 8–10 mm., breadth 1.5–2.5 mm. Body flattened, lanceolate, attenuated toward both extremities, especially the anterior (Fig. 4791). Suckers separated by about one-fifth total length; diameter of oral sucker about 0.5 mm., of ventral about 0.6 mm. Intestinal crura terminate one-fifth of total length from posterior end. Genital pore at intestinal fork. Testes slightly right and left of median line. Vitellaria from posterior testis through about the middle fifth or fourth of body. Loops of uterus extending laterally beyond intestinal crura. Eggs 0.038–0.045 by 0.022–0.030 mm., thick-shelled, dark brown when deposited, and containing a spherical or oval miracidium ciliated only at anterior end and supplied with rudimentary intestine and boring spine.

Parasitic in gall ducts of herbivorous and omnivorous mammals very generally, often in common with *Fasciola hepatica*. Among the hosts given are sheep, cattle, horse, ass, deer, goat, hare, rabbit, pig, and man. The records in accordance with which this species occurs in dog and cat rest on confusion with *Opisthorchis felineus*.

The development of the species is unknown. Leuckart found that the miracidia spontaneously desert their shells in the intestine of certain slugs (*Arion*, *Limax*), but that no further development could be induced here or in other snails. On the basis of a single feeding experiment, however, he considered small species of *Planorbis* from fresh water to be the larval host. Piana conjectured that land snails were more probably responsible. No further evidence has been obtained.

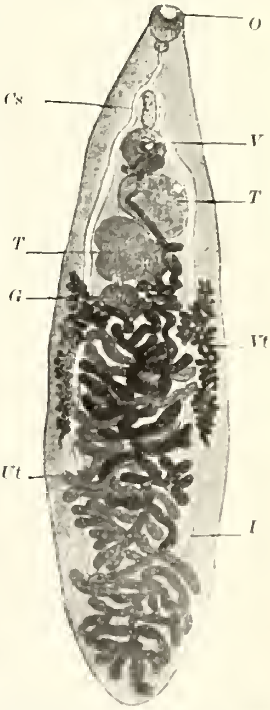

FIG. 4791.—*Dicrocœlium lanceatum* Stiles and Hassall. × 12. (After Braun.)

The distribution of this species is less extended than that of *Fasciola hepatica*, though in general much the same. Leuckart believed it more abundant in southern Europe than in the north. It is wanting in England, but has been recorded among extra-European countries in northern Africa, Siberia, Turkestan, North and South America.

Seven cases of human infection are on record. They come from Germany, Bohemia, Italy, France, and Egypt. With possibly a single exception the parasite was not the cause of any apparent trouble. In view of this absence of dangerous symptoms Braun conjectures that mild infections may be much more frequent than is known.

The family of the Schistosomidæ Looss contains flukes of separate sexes with the male shorter and thicker than the slender female, and having a canal formed by the ventrally turned margins of the body. The acetabulum is stalked and the intestinal crura unite posterior to it. Only one genus is important here.

Schistosoma Weinland 1858.—Female filiform; male very broad with body rolled together ventrad to form completely closed *canalis gynæcophorus*. Suckers near together. No pharynx. Intestinal crura in male join often far back. Genital pore in both sexes median, post-acetabular, no copulatory organs. Testes of five to six vesicles. Seminal vesicle small. Uterus of female very long, at times with large numbers of eggs. Eggs tapering equally to both ends with small terminal spine at posterior end, without lid. In venous system of mammals.

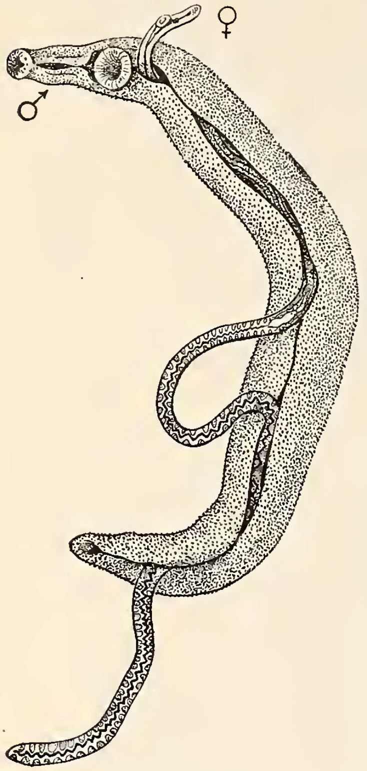

Fig. 4792.—*Schistosoma hæmatobium* (Bilharz). Male and female *in copula* and before the beginning of the production of eggs. × 12. (After Looss.)

Schistosoma hæmatobium (Bilharz 1852).—(Syn.: *Distoma hæmatobium* Bilharz 1852; *Gynæcophorus hæmatobius* Diesing 1858; *Bilharzia hæmatobia* Cobbold 1859; *Thecosoma hæmatobium* Moq.-Tand. 1860; *Bilharzia capensis* Harley 1864.) Male 4, or usually 10–14 mm. long, 1 mm. broad, 0.14–0.17 mm. thick; female 8, or usually 13–20 mm. long, 0.28 mm. broad, 0.21–0.25 mm. thick, oral sucker 0.2 mm. in male, 0.07 mm. in female. Acetabulum pedunculate; diameter 0.28 mm. in male, 0.059 mm. in female. Eggs 0.12–0.19 mm. long, 0.05–0.073 mm. broad, spindle-shaped with median enlargement and with rudimentary filament at posterior end.

Structure.—Through the admirable recent studies of Looss the earlier work of Leuckart and others has been confirmed and extended so that a precise account can now be given of this unique form. The two sexes must be considered separately save that both agree in the delicacy of structure consonant with their existence in the blood current. The male (Fig. 4792) shows papillæ or warts over the entire dorsal surface, except near both ends of the body. Fine dermal spines cover the suckers both within and without. Slightly larger spines cover ventral surface of the body from the genital pore to the posterior tip, *i.e.*, the so-called *canalis gynæcophorus*, as well as form a zone on the dorsal margin of that side which lies within in the formation of the canal. A pharynx is wanting and the œsophagus with two expansions (*A*, *B*, Fig. 4794) covered with a layer of salivary cells terminates at or near the acetabulum, branching to form the intestinal crura. These may join soon to form the unpaired cæcum, which extends in the median line nearly to the posterior end, or their junction may not occur until the posterior fifth of the body is reached; one also finds the crura separating for short intervals in the course of the unpaired cæcum. The food mass in the alimentary canal of the parasite consists chiefly of leucocytes with pigment from the liver and a few erythrocytes.

The reproductive system departs widely from that of other Trematoda described in general above, first in that the sexes are separate, but secondly and equally strikingly in its structure. In the male (Fig. 4794) the testes, four or five in number, lie alternately right and left of the median line not far behind the acetabulum. As the apparent common duct is in reality a part of the organ, the group represents rather a very deeply lobed single testis. The short duct joins this to the sausage-shaped seminal vesicle, from which a short simple canal extends to the sexual pore. This pore is always located exactly at the entrance to the canalis gynæcophorus. Special copulatory organs and glandular adnexa are entirely wanting.

The body of the female is smooth except on the inner surface of the suckers, where extremely fine spines are numerous and the posterior tip of the body, which carries much stronger spines, pointed in various directions. A pharynx is wanting; the œsophagus with dilatations and gland cells, as in the male, divides anterior to the middle of the acetabulum, to form the intestinal crura, which unite behind the germarium to proceed as an unpaired cæcum in a zigzag line, with regularly alternating lateral diverticula to the posterior end.

The female reproductive system (Fig. 4793) lies largely between the acetabulum and the posterior junction of the intestinal crura. Just anterior to this junction one finds the median, elongated oval germarium. The single vitellarium with symmetrical follicles right and left of the intestinal cæcum, occupies the posterior end of the body. Its duct lies parallel to the germ duct coming from the posterior end of the germarium, and joins it at the shell gland, which is located a short distance anterior to the germ gland. After a short ootype the uterus extends nearly directly as a tube of uniform calibre in the median line to the genital pore which lies immediately behind the acetabulum.

The egg (Fig. 4795) has the form of a compressed spindle somewhat inflated at the middle. At the posterior pole one finds a short irregular tip, homologous to the filament on the eggs of ectoparasitic trematodes. In those eggs which are discharged in urine this process is terminal, in such as remain in the body of the host it is slightly lateral. The egg shell contains a mature embryo, cylindrical in form with conical anterior tip, or papilla, and covered by a coating of fine cilia. A rudimentary alimenatry canal, cephalic gland, and the usual masses of germ cells in the posterior end are easily distinguishable.

All authorities, save one, agree that the embryos do not hatch out if the eggs are left in unaltered urine, but that the addition of fresh water, especially if warm, brings about at once the opening of the shell and escape of the embryos. If left in urine the embryos die in the shell in from six to twenty-four hours. The further fate of these embryos is entirely unknown, as also the manner of infection. It has been conjectured that the sporocsyt stage also occurred in the human host, but the experiments of Looss on apes were without result.

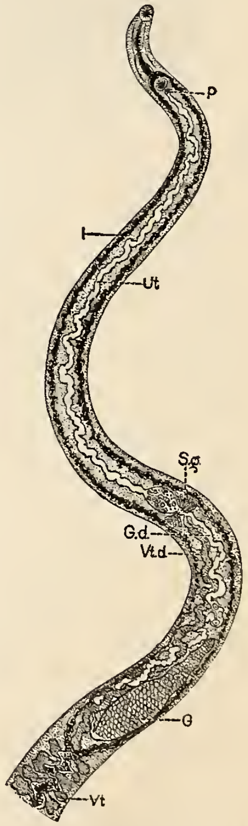

Fig. 4793.—*Schistosoma hæmatobium* (Bilharz). Anterior region of female in ventral aspect. The uterus does not contain as yet any developing ova. Letters as before. × 19. (After Looss.)

This species occurs as a parasite in the portal system of man, perhaps also in the Sooty monkey and in cattle.

It is widely distributed in Africa, records being at hand of its occurrence in Egypt, along the eastern coast, at Cape of Good Hope, and at points on the western and northern shore as well as in the interior. It is very common among the Egyptian laborers, and boys and youths seem to be particularly susceptible to its attacks. One-third or more of those examined by different observers were found to harbor the parasite. The centre of infection at Mecca (Arabia) is regarded as introduced, and that recently discovered on the island of Cyprus is probably similar.

A case has just been reported by Manson in which the eggs were found in the fæces but not in the urine of an Englishman in the West Indies, who had never been in any country where the parasite is known to exist. On account of its peculiar features the case needs confirmation, but if correct demonstrates the existence of a new centre of infection near our shores.

Stiles says that the human blood fluke has been found twice in this country; once in a foreigner on the "Midway" during the Columbian Exposition and once in New York City. I have found another case recorded from Georgia. All these cases were certainly infected elsewhere, and there is no evidence to show that the parasite has been able to gain a footing as yet in this country.

Pathology.—The females apparently go into the venous plexus of the pelvis to oviposit, and the eggs are carried thence by the blood current into various organs. Here they accumulate, occluding the vessels and causing various symptoms according to the organ affected. Such accumulations have not been found as yet in spleen, stomach, or pancreas. In the lungs they determine lesions which simulate those in miliary tuberculosis, and though rarely recorded as yet are believed to be common. Tumors of similar origin have been rarely met with in mesenteric ganglia, on the peritoneum and in the skin.

In the liver cirrhosis and biliary calculi are produced by their presence. More frequently one can trace them to the walls of the urinary passages or of the large intestine, and here more serious difficulties arise. Catarrh of the bladder and pain in the lumbar region ensue and are accompanied by the appearance of blood or bits of blood and pus at the close of micturition, which at first occur only occasionally but later regularly. This so-called Egyptian hæmaturia, or bilharziosis as it is called after Bilharz, the discoverer of the parasite, can be definitely diagnosed by the microscopical demonstration of the eggs in the urine. It should be noted, however, that these may be present in the urine without the least trace of blood. The disease may continue for some time, even six to eight years, and eventually terminate without more extended symptoms.

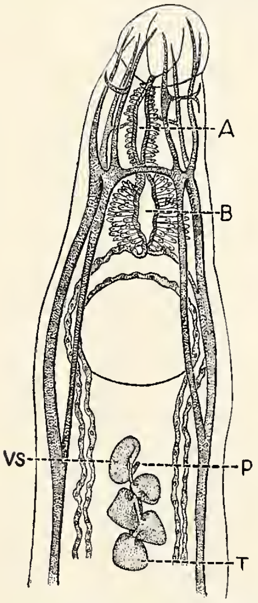

FIG. 4794.—*Schistosoma hæmatobium* (Bilharz). Anterior end of male showing male genital organs and also in part nervous and alimentary systems; *A*, *B*, enlargements of œsophagus with glands; *P*, sexual pore; *T*, testis; *VS*, seminal vesicle. × 48. (After Looss.)

Renewed or reinforced infection, however, intensifies the cystitis and often brings about urethritis as well. Frequently one finds urinary calculi, in many of which the nucleus of the calculus can be shown to consist of one or more fluke eggs. In Egypt one series of observations showed the coincidence of bilharziosis with lithiasis in eighty per cent. of observed cases. In more severe cases the changes may extend to the ureters, kidneys, and colon. The urine contains larger amounts of blood and eggs, and the fæces present a similar appearance. The symptoms then resemble tropical dysentery, and Bilharz, the discoverer of this parasite, originally connected the two in a causal way. As a result of the changes outlined, nutrition suffers and finally death ensues from uræmia, pyæmia, pyelonephritis, or general marasmus. The wall of the bladder shows under these conditions excessive thickening, together with the formation of excrescences, 1–2 cm. in diameter, filled with the eggs of the parasite; the cavity of the organ is diminished materially, and also the elasticity of its wall. Extensive ulcerations are not uncommon, and in connection with the rupture of small vessels determine the characteristic hæmaturia.

The disease cannot be regarded as necessarily fatal; its severity depends in general upon the degree of infection. In cases of moderate intensity appropriate treatment of a general character effects a noteworthy amelioration, and in many cases at least the disease is self-terminating. Anthelminthics and other medicaments have been employed with variable results.

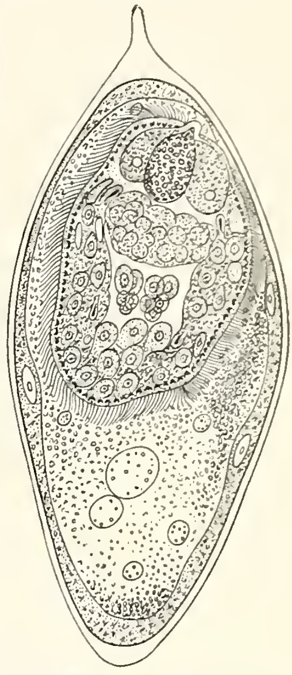

FIG. 4795. — Egg of *Schistosoma hæmatobium* (Bilharz). × 500. (After Looss.)

Infection is generally attributed to the use of impure water from pools and canals. It has been observed that those villages supplied directly from the Nile are badly infected, while in those using filtered water the parasite is almost unknown. Looss has urged strong reasons in favor of the view that bathing affords the opportunity for the parasite to enter the body through the skin. Both the means of infection and the subsequent course of the parasite in reaching its location in the portal system are, however, entirely conjectural. *Henry B. Ward.*

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Also numerous shorter papers by the same authors, Askanazy, Cobbold, Ijima, Leidy, Lühe, Railliet, Yamagiwa, White, and others.

TRENTHAM SPRING.—Campbell County, Georgia. Post-Office.—Fairburn.

Access.—Viâ Atlanta and West Point Railroad to Fairburn, thence by private conveyance three miles north to spring.

For a number of years this spring had considerable local reputation. The principal ingredients of the water are as follows: Calcium carbonate, magnesium carbonate, iron carbonate, potassium carbonate, magnesium sulphate, sodium chloride, alumina, organic matter. The waters of this spring are said to be highly efficacious in the treatment of syphilis and scrofula.

James K. Crook.

TREPANNING; TREPHINING.—By common consent these terms are applied, not merely to the application of that form of circular saw known as the *trepan* (or diminutive *trephine*), but to any procedure by which a piece of bone is elevated, or is removed, in order to permit the elevation of some adjoining portion, or the exposure of the membranes or brain beneath. The operation dates back to the remotest antiquity, and seems to have been practised at various times among various peoples as a rite or ceremony. Except when performed by surgeons, it seems to have been done usually with the rudest of implements, and even the instruments used by the previous generation of surgeons were in most respects clumsy and coarse.

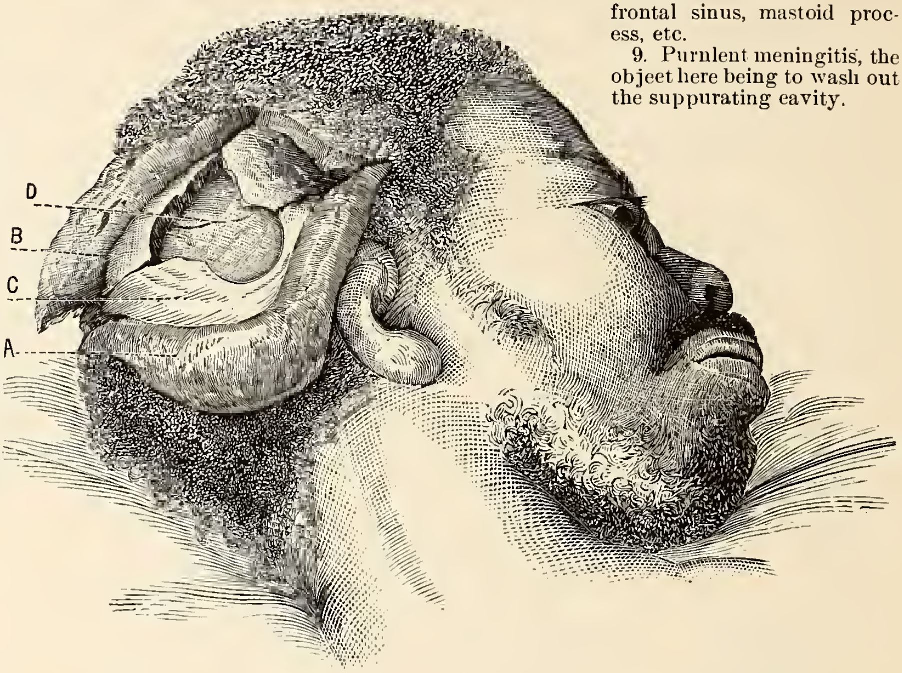

Fig. 4797.—1, A Fractured Skull after the Application of the Trephine and the Removal of the Fragments. (After Charles Bell.) *A*, *B*, The flaps of integument; *C*, the cranium; *D*, the dura mater exposed.

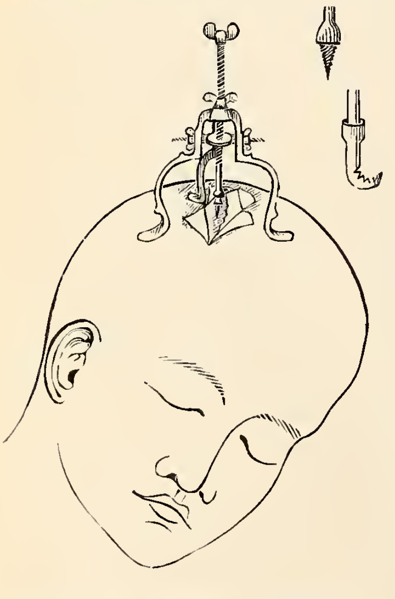

Fig. 4796.—The Operation of Trepanning in the Early Part of the Eighteenth Century. (From Heister.)

Indications.—1. Simple fractures of the skull, with signs of compression.

2. Compound fractures, with depression, even without signs of compression, except over the frontal sinus, in adults.

3. Punctured and gunshot fractures, even without symptoms. (The reader is referred to the article on *Head, Wounds of*, in Vol. IV. of this Handbook, where I have considered these indications in greater detail.)

4. Coma, with signs of compression, contusion, or laceration of soft parts, without fracture of the external table.

5. Hemorrhage. The operation is done in this case either to tie a vessel or to remove a clot. This is partially included under heading 4.

6. Abscess of brain.

7. Tumor of the brain or meninges.

8. Bone abscess in the frontal sinus, mastoid process, etc.

9. Purulent meningitis, the object here being to wash out the suppurating cavity.

10. Acute infectious osteomyelitis of the diploë.

11. Epilepsy or insanity, when any lesion can be localized with sufficient definiteness.

12. To afford a so-called "relief opening," for relief of pain or cerebral irritability. (See also under *Brain, Surgery of.*)

Each one of the foregoing conditions is an indication for working through and underneath one or both tables of the skull, in order to effect whatever may be possible beneath the level of the bone removed. The various conditions are discussed in their appropriate places; we speak here only of that which pertains to the operation proper.

Dangers.—The South Sea Islanders scrape through each other's skulls with pieces of glass, we are told, and with impunity. Among the Cornish miners the operation was, up to a comparatively recent date, according to Michel (*American Journal of the Medical Sciences*, October, 1879), one of daily occurrence. The Count of Nassau was trephined by Chadbourn some twenty-seven times. And all this at a time when, or among a people in whom, fear of sepsis has not prevailed. And yet, until very recently, there has been a recognized school of practising surgeons who have uttered solemn warnings against even a properly discriminating resort to the procedure, and fierce wordy battles have been waged concerning it. But the medical profession is now almost a unit in favor of a diagnostic use of the instrument, as it is in favor of an exploratory abdominal section. We are now in a position where one may boldly affirm, even in courts of law, that *trephining is not, by itself, a dangerous operation, when properly done*, but it must be insisted that the *proper* performance of the operation includes the most careful attention to antiseptic or aseptic

Protozoa

ings—and the other showing the schemes of declension of adjectives.

TABLE SHOWING DECLENSION AND GENDER OF NOUNS OCCURRING IN TITLES OF U. S. PHARMACOPŒIAL MEDICINES AND IN COMMON PRESCRIPTION TERMS.

Nominative singular ending in **-a:**
All First Declension and Feminine, except (of Greek origin) *the following* in *-ma:*

Physosti'gma (physostig'matis), 3*d*, *n*.
Aspidospe'rma (aspidospe'rmatis), 3*d*, *n*.
E'nema (ene'matis), 3*d*, *n*.
Catapla'sma (catapla'smatis), 3*d*, *n*.
Gargari'sma (gargari'smatis), 3*d*, *n*.
Theobro'ma (theobro'matis), 3*d*, *n*.

Nominative Singular ending in **-us:**
All Second Declension, Masculine, except—

Juni'perus, 2*d*, *f*.
Pru'nus, “
Rha'mnus “
Sambu'cus, “
U'lmus, “
Rhus (rho'is), 3*d*, *f*. (“rhus glabra”).
Fru'ctus, 4*th*, *m*.
Spi'ritus, “
Que'rcus, “

Nominative Singular ending in **-os:**
Comprise only the following—

Flos (flo'ris), 3*d*, *m*.
Bos (bo'vis), 3*d*, *m*. or *f*.

Nominative Singular ending in **-um:**
All Second Declension, Neuter.
Nominative Singular ending in **-on:**
Comprise only the following—

Eriodi'ctyon, 2*d*, *n*.
Hæmato'xylon, “
Toxicode'ndron, “
Eri'geron (erigero'ntis), 3*d*, *n*.
Li'mon (limo'nis), 3*d*, *m*.

Nouns of all other endings are of Third Declension, and are as follows:

Ending in **-c:**
Lac (la'ctis), *n*.

Ending in **-el:**
Fel (fe'llis), *n*.
Mel (me'llis), *n*.

Ending in **-en:**
Alu'men (alu'minis), *n*.
Se'men (se'minis), *n*.

Ending in **-o:**

(*-io*)
Confe'ctio (confectio'nis), *f*.
Lo'tio (lotio'nis), *f*.
Po'rtio (portio'nis), *f*.
Tritura'tio (trituratio'nis), *f*.

(*-ago*)
Mucila'go (mucila'ginis), *f*.
(*-bo* and *-po*)
Ca'rbo (carbo'nis), *m*.
Pe'po (pepo'nis), *m*.
Sa'po (sapo'nis), *m*.

Ending in **-r:**

(*-er*)
Æ'ther (æ'theris), *m*.
Pi'per (pi'peris), *n*.
Zi'ngiber (zingi'beris), *n*.

(*-or*)
Li'quor (li'quoris), *m*.
(*-ur*)
Su'lphur (su'lphuris), *n*.

Ending in **-s:**

(*-as*, genitive *-atis*)
Ace'tas (aceta'tis), *m*.
[*and all salt-names in -as.*]

(*-as*, genitive *-adis*)
Ascle'pias (asclepi'adis), *f*.
(*-is*, genitive *-itis*)
A'rsenis (arseni'tis), *m*.
[*and all salt-names in -is.*]

(*-is*, genitive *-idis*)
A'nthemis (anthe'midis), *f*.
Ca'ntharis (cantha'ridis), *f*.
Colocy'nthis (colocy'nthidis), *f*.
Hamame'lis (hamame'lidis), *f*.
I'ris (i'ridis), *f*.
Ma'cis (ma'cidis), *f*.

(*-is*, genitive *-eris*)
Pu'lvis (pu'lveris), *m*.
(*-is*, genitive *-is*)
Ca'nnabis (ca'nnabis), *f*.
Digita'lis (digita'lis), *f*.
Hydra'stis (hydra'stis), *f*.
Sina'pis (sina'pis), *f*.

(*-os*, *see ante.*)

(*-us*, *see ante.*)
(*-ns*)
Ju'glans (jugla'ndis), *f*.
(*-ps*)
A'deps (a'dipis), *m*.
(*-rs*)
Pars (pa'rtis), *f*.

Ending in **-x:**

(*ax*)
Bo'rax (bora'cis), *m*.
Sty'rax (styra'cis), *m*.
(*-ex*)
Co'rtex (co'rticis), *m*. and *f*.
Ru'mex (ru'micis), *f*.

(*-ix*)
Pix (pi'cis), *f*.
Ra'dix (radi'cis), *f*.
(*-ux*)
Nux (nu'cis), *f*.,
(*-lx*)
Calx (ca'lcis), *f*.

TABLE SHOWING SCHEMES OF DECLENSION AND GENDER OF ADJECTIVES OCCURRING IN U. S. PHARMACOPŒIAL MEDICINAL TITLES AND IN PRESCRIPTION-PHRASES.

SCHEME I.—*Second and First Declensions Combined.*

Masculine.	*Feminine.*	*Neuter.*
-us [2d dec.]	*-a* [1st dec.]	*-um* (*-on*) [2d dec.]

SCHEME II.—*Third Declension.*

Masculine and Feminine.	*Neuter.*
-is (genitive *-is*).	*-e* (genitive *-is*).

SCHEME III.—*Third Declension.*
Masculine and Feminine.
-or (genitive *-oris*).

SCHEME IV.—*Third Declension.*
All Genders.
-ens (genitive singular *-entis*); (genitive plural *-entium*).

In commentary upon the declension schemes of adjectives set forth in the foregoing table, it may be stated that Scheme I. embraces by far the greater number of adjectives. In this scheme the neuter ending *-on*, borrowed from the Greek like the same ending among nouns of the second declension, finds among drug titles but a single example, *diachylon*. Scheme II. embraces a few adjectives only among those occurring in medicine titles, and affords an example of the nominative ending *-e* of the third declension, which does not occur among *nouns* of pharmacopœial titles. Scheme III. offers a single example only, viz., *fortior*. Of Scheme IV. pharmacopœial adjectives give but two examples, namely, *effervescens* and *recens*. A survey of the *genders* marked on the table shows that in every case a distinctive gender, where there is such, can be told from the adjective nominative ending.

A final point, concerning the expression of a prescription, is that, having regard to the fact that a *slip of the pen* on the part of the writer, or a *slip of the understanding* on the part of the pharmacist reader of a prescription, may convert what was meant as a missive of mercy into a death warrant, it behooves the prescriber most solemnly to execute his task *deliberately*, *thoughtfully*, and, in chirography, *legibly*, *abjuring all dangerous cloak-of-ignorance abbreviation of medicine-titles;* and, finally, to fail not of that trusty safeguard against error, a *review of the paper* after the writing. *Edward Curtis.*

PROTOZOA.—Standing distinctly as the lowest of all animal organisms, the protozoa constitute a branch differentiated from higher groups by the simplicity of organization in that the animal consists of but a single cell or a colony of simple cells. In the main the animals of this group are easily recognized, although some forms are so generalized, and partake of plant characteristics to such an extent as to render their classification doubtful; and, on the other hand, certain higher forms show the first stages in specialization among cells of the colony which ultimately leads to the differentiation of the metazoan organism.

The Protozoa are true cells and possess consequently neither organs nor tissues. In the discharge of all living functions by the single cell, however, one finds a physiologic complexity as striking as the morphologic simplicity. The latter is also less extreme in many cases where specialization has effected the production of individual features within the single cell, differentiations which subserve particular functions, and which are thus analogous to the organs of the metazoa. Such are denominated cell organs, or organellæ, and are of great variety. Among these may be mentioned the locomotor structures, such as pseudopodia, flagella, and cilia, the numerous vacuoles of a nutritive and contractile type, the preformed, often highly modified openings for ingestion of food and egestion of solid waste matter, and various protective coverings of a permanent character or temporary and connected with reproduction.

As true cells all Protozoa possess one or more nuclei, and the earlier contention that there exists a special group of anuclear organisms, the monera of Haeckel, has not been confirmed by later study. The simple protozoon is with a single known exception (*Loxodes rostrum*) uninuclear, and the presence of many nuclei points to a colonial organism or to a reproductive phase, except that in one large group two forms of nuclei coexist and divide the functions otherwise resident in the single nucleus.

The reproduction of the Protozoa is again that of the cell, viz., by division, which may be simple or multiple, and in varied form, either while free or in the encysted condition. Two types of division may alternate regularly or indefinitely in the life cycle of a given species, and in most subdivisions of the group certain so-called sexual processes have been demonstrated. These consist in general in the fusion of similar individuals (isogametes), or of dissimilar (macro- and microgametes), or merely in the mutual exchange of nuclear matter.

In regard to location parasitism among the Protozoa affords conditions not found otherwise. There are in this group not only organ parasites, as in the groups of helminthes, but also such forms as must be designated tissue parasites, cell parasites, and even nuclear parasites. Different phases in the life cycle of the same species may illustrate different modes of parasitism, as is the case with the malarial organisms, which at various epochs in the life history are successively cell parasites in the erythrocytes, organ parasites in the blood-vessels, and tissue parasites in the wall of the mosquito's midgut.

In general, however, the protozoan parasites repeat conditions already described for Metazoa. One finds the degeneration of organs superfluous under conditions of parasitic existence, the formation of organs of attachment, such as hooks, suckers, etc., the noteworthy fecundity already commented upon for metazoan parasites; and finally the alternation of generations and of hosts is a common feature among the Protozoa also.

An encysted condition of the entire individual or of a group of spores aids in the dispersal of the species, which are all inhabitants of a moist environment and cease activity at once on withdrawal of the water. This general habit renders it difficult to distinguish between mere commensals which find in the alimentary canal of higher forms conditions for their ordinary slime-inhabiting existence without exerting any influence upon the host, and such as are parasites in the true sense.

A true parasite draws its nourishment from the host and affects it at least to that extent. When this takes place, as with protozoan parasites largely, within a tissue or even a cell, morbid conditions are evoked, even though they remain local in some cases. That functional disturbances result is evinced by the relatively large number of protozoan diseases among animals and plants. These sometimes take the form of tissue proliferations, as has been clearly demonstrated for plants. An effort to trace similar effects in animals is found in the extensive literature on cancer parasites. Thus far, however, no sufficient evidence has been brought to establish the parasitic nature of such abnormal growths, and none of the supposed "parasites" can be clearly recognized as Protozoa. It should be noted in passing that in addition to the mechanical effect of cell parasites a chemical influence of at least equal importance is exercised by the excretions of the organism, the metabolic products set free in the protoplasm of the host cell. In some cases this is a factor of great importance, as also in the case of bacterial diseases; its significance among Protozoa is not yet sufficiently investigated.

It is noteworthy that in many instances a protozoan infection is self-terminating, either that a type of immunity is acquired by the host, or that the reproductive cycle of the parasite reaches its limit without a change of host or alternation of generations. MacNeal and Novy have recently endeavored to determine experimentally the possibility of securing attenuated cultures of one protozoan parasite (*Trypanosoma*) with absolutely negative results; the last generation from a culture more than a year old was even more virulent than the organism at the start.

Regarding means of infection but little definite evidence is at hand. It is inferred that encysted forms furnish the ordinary means for transferring the species to a new host, and yet in many cases experiments along this line have been without results. In other cases it is now known that the transfer takes place through some biting insect, which in some cases, if not all, acts as the host for another phase in the life history of the parasite, and is capable of transmitting the disease only after a period sufficient to allow of the development within its body of the specified portion of the life cycle.

In those cases in which the life history has been worked out, means of preventing the infection of the human host constitute the evident limitation to the spread of the disease caused by the parasite. The inauguration of a simple but effective prophylaxis for malaria and yellow fever ranks rightly as among the most brilliant achievements of scientific medicine. In cases in which the life history of the parasite is unknown, the prophylaxis is necessarily vague and uncertain. It is wise to emphasize here the importance of co-operative effort on the part of trained observers, both in medicine and in zoology, to elucidate fully the problems which necessarily offer almost insuperable obstacles to the investigator approaching them from the single standpoint.

All the varied modifications within the branch of Protozoa may be grouped into four well-defined classes which are now almost universally recognized. These may be briefly outlined together with their major subdivisions, following in the main the classifications of Bütschli, Calkins, and Doflein, and noting principally those groups which contain forms found in the human body.

Class I. Sarcodina.—Naked or shelled Protozoa, characterized in the free adult condition by the formation of changeable processes of protoplasm as organs of locomotion. These pseudopodia may be lobose, digitate, reticulate, or finely radiate, and may be formed over the entire surface of the body, or only at definite points. Reproduction takes place by simple division and by spore formation.

Subclass 1. Rhizopoda. Naked or shelled Sarcodina, having lobose or reticulate pseudopodia. The young may be flagellate as well as amœboid, and are produced by multiple division of the active cell or during encystment. Included among Amœbina are naked forms (Gymnamœbina) with both free and parasitic species, and also shelled forms (Thecamœbina) only free living.

Subclass 2. Heliozoa. Naked or shelled Sarcodina, typically spherical, with little change of form by amœboid movements. Pseudopodia fine, filiform, radiating from all parts, provided with axial filament and rarely changeable, exclusively free living forms.

Subclass 3. Radiolaria. Marine Sarcodina with pseudopodia like those of Heliozoa, but always provided with internal chitinous capsule which encloses the nuclei. Skeleton of acanthin or silica sometimes absent. A very large group of free living forms.

Subclass 4. Mycetozoa. Terrestrial saprophytic or parasitic forms, also known as Myxomycetes or slime moulds, and included under the fungi by some botanists. The motile amœboid or flagellate swarm spores, the plasmodia or colonies formed by the fusion of numerous amœboid individuals, and the holozoic mode of nutrition are characteristically animal features. On the other hand, the production of spores in sporangia, often provided with stalks and other plant-like structures, are taken to prove the plant nature of these forms. All known parasitic forms in this group attack plants.

Class II. Mastigophora.—Protozoa of variable form, naked or with cell membrane; they move by flagella, which vary in number from one to eight on each cell.* Mouth, contractile vacuole, and definitely formed nucleus usually present. Small forms with tendency to formation of colonies.

Subclass 1. Flagellata. Small organisms with one or more flagella at anterior end, usually actively motile, but capable of encystment. Reproduction by longitudinal fission of free form or by multiple division in encysted stage. Rarely transverse fission occurs.

Subclass 2. Dinoflagellata. Naked or shelled forms with two flagella, one of which extends out from the body, while the other is wrapped around the animal. No parasitic forms.

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* *Multicilia lacustris* Cienkowsky has many flagella, distributed over the whole body.

Subclass 3. Cystoflagellata. Large marine forms with parenchymatous protoplasm and firm membrane; marine; no parasitic forms.

Class. III. Sporozoa.—Exclusively parasitic forms, in the adult condition without flagella or cilia, contractile vacuole, and opening for ingestion of solid food. Reproduction always by spore formation, usually within a firm membrane. Alternation of generations only exceptionally wanting. The young forms regularly begin the life cycle as cell parasites; other stages may be the same, or tissue or organ parasites.

Subclass I. Telosporidia.—At the end of a vegetative period the entire cell divides into sporocysts.

Order 1. Gregarinida. Vegetative stage intracellular at first, full-grown organism extracellular; fertilization isogamous, fertilized forms permanently extracellular. A large group of forms parasitic in alimentary and body cavities of invertebrates.

Order 2. Coccidiomorpha. Vegetative stage permanently intracellular; fertilization anisogamous; sexual generation permanently or temporarily intracellular. Many of the most important protozoan parasites of man fall in the limits of this group.

Subclass 2. Neosporidia.—Sporocysts are produced continually and at the expense of only part of the cell. In general these forms are not well known.

Order 1. Cnidosporidia. The spores possess one or more polar capsules which contain a coiled thread like a nematocyst. The sub-orders are: (1) Myxosporidia, parasitic in water-inhabiting vertebrates; and (2) microsporidia in certain invertebrates also. Both are not important here.

Order 2. Sarcosporidia. Parasitic in muscle cells of terrestrial vertebrates, probably without polar capsule. Little known, but important.

Class IV. Infusoria.—Protozoa with motor organs in the form of cilia, whether simple or united into membranes, membranellæ, or cirri; with macro- and micronucleus; reproduction by division and by budding, combined with an exchange of nuclear matter known as conjugation.

Subclass 1. Ciliata. Cilia persistent except when encysted. Cytostome usually present. Mostly free forms; some parasites of man and other animals.

Subclass 2. Suctoria. Cilia only on young swarming stage. Food taken in by special sucking tubes; no cytostome. No human parasites.

According to this classification the forms which have been reported from man may be arranged as given in the following list, in which, however, chiefly those species are included which are definitely accepted. Some few doubtful forms of special significance are listed here; and still others are referred to in the text under general headings.

- Class Sarcodina.
  - Subclass Rhizopoda.
    - Order Amœbina.
      - Suborder Gymnamœbina.
        - Entamœba coli.
        - Entamœba histolytica.
        - Amœba Miurai.
        - Leydenia gemmipara.
- Class Mastigophora.
  - Subclass Flagellata.
    - Order Protomonadina.
      - Cercomonas hominis.
      - Monas pyophila.
      - Trypanosoma gambiense.
      - Cystomonas urinaria.
    - Order Polymastigina.
      - Trichomonas vaginalis.
      - Trichomonas intestinalis.
      - Lamblia duodenalis.
- Class Sporozoa.
  - Subclass Telosporidia.
    - Order Coccidiomorpha.
      - Suborder Coccidia.
        - Eimeria Stiedæ.
        - Eimeria hominis.
        - Eimeria bigemina.
      - Suborder Hæmosporidia.
        - Plasmodium malariæ.
        - Plasmodium vivax.
        - Plasmodium immaculatum.
  - Subclass Neosporidia.
    - Order Sarcosporidia.
      - Sarcocystis Lindemanni.
- Class Infusoria.
  - Subclass Ciliata.
    - Order Holotricha.
      - Chilodon dentatus.
    - Order Heterotricha.
      - Nyctotherus faba.
      - Balantidium coli.
      - Balantidium minutum.

The relation of the Protozoa to disease is only just beginning to be investigated. At every point the student is met by the gross insufficiency of present knowledge; a host of isolated observations is on record. Some are clearly wrong, while others are indicative of important discoveries, though the presence of certain organisms during specific diseases needs confirmation, and equally their relation to the inception and progress of the malady. New methods must be worked out for the culture no less than the study of these forms, and the same sort of rigorous analysis is demanded in demonstrating their relation to disease which has been given to bacteria. It seems altogether probable that they will play a prominent rôle in medical investigation in the near future, but in the present state of our knowledge any review of the group must necessarily be only a tentative one.

The class of Sarcodina, or sarcode animals, is typically represented by the common free-living amœba, which has its parallel in the white blood cells. The most characteristic structural feature is the ability to protrude a portion of the body substance in the form of a process or pseudopodium by which locomotion is achieved, and also the food particles are seized and engulfed. The subdivision of the class rests primarily upon the precise character of the pseudopodia.

Under the order Amœbina are included such forms as possess lobose pseudopodia, and the sub-order of Gymnamœbina embraces such of these as are without a shell. All the human parasites which fall within the Sarcodina are included in a few closely related genera of this suborder. While the structure is simple, and in agreement with that of the simple free-living forms of the group, it is impossible to demonstrate that this is not the result of degeneration from more highly differentiated forms by virtue of the parasitic mode of existence. The parasitic species are most probably to be traced back to slime-inhabiting, free-living forms, a transition from which to the present parasitic existence seems most immediate and simple in physiological adjustment.

The ordinary method of reproduction is by simple division, recurring at frequent intervals and conserving the rapid multiplication of the species. This form has long been known, and is to be observed frequently in all truly independent organisms of this type. Recent investigations have disclosed another reproductive type: under definite circumstances, possibly only after fusion of individuals or some exchange of nuclear matter, the amœba forms a cyst within which the nucleus undergoes multiple division, and ultimately the protoplasm arranges itself about the new nuclei, so as to give rise to an equal number of small amœbæ. When these desert the cyst there is left behind a residual mass of protoplasm. At first distinguishable slightly in structure as well as size, the small amœbæ thus produced soon grow to the size and appearance of the adult. The occurrence of this stage in the life cycle has not yet been demonstrated for parasitic amœbæ, except very recently for *Entamœba coli* and *E. histolytica*: but if present it may well be related to the spread of the species as found in the change of hosts. The necessity for such a stage would explain the ineffectual attempts which have been made to inoculate new hosts by direct transference of the ordinary parasitic form.

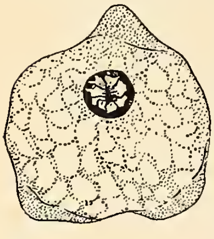

FIG. 5163. — "*Amœba coli*," Stained Preparation. Magnified. (After Doflein.)*

In the genus *Amœba* the separation of species is exceedingly difficult on account of the insignificant features available for purposes of differentiation. There are those who lump the forms found in man with such as occur in other mammals under a single species, and there are also those who contend that each host shelters a distinct parasitic species, and bring as evidence the individuality of parasitism in other groups. But on the other hand it may be urged that the amœbæ are not highly differentiated as parasites, and mere difference in host animal has long since been abandoned as a distinguishing mark between parasites from higher classes. It is certain that no positive statement can be made until more complete information is obtained regarding the life cycle of the species. At present no one can affirm that a given species does not possess a free-living generation as well, or even that it is not a normal free-living form which under favorable circumstances has taken up the parasitic mode of life; in which case it should be regarded as a mere accidental parasite. Furthermore of only one human parasite included within this group can it be said positively that it is more than a harmless commensal. Although facts have been adduced to show that others also play a pathogenic rôle, the question must still be regarded as at least an open one.

Among the amœboid bodies which one finds in nature and in cultures many are only developmental stages rather than independent organisms, and the same may well be true of some of the parasitic forms. On the other hand, the distinction between such organisms and various structural elements of the human body is often a very difficult task, and some of the purported parasitic species are in fact referable to the misinterpretation of the body cells referred to above.

In the new genus *Entamœba* are included two important human parasites, the life history of which has recently been well elucidated. The other imperfectly known species are left in the old collective genus *Amœba*, but fuller knowledge may result in the transfer of some or all to this same or other new genera according to the facts ascertained regarding the life history of the individual forms.

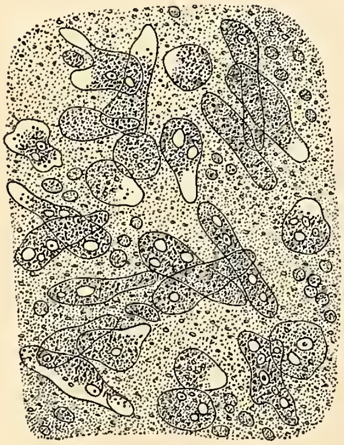

FIG. 5164.—"*Amœba coli*," in Intestinal Mucus. Magnified. (From Braun, after Lösch.)*

Entamœba coli (Lösch 1875).—(Syn.: *Amœba coli* Lösch 1875; [?] *Amœba dysenteriæ* Councilman and Lafleur 1891; *Entamœba hominis* Casagrandi e Barbagallo 1897; *Entamœba coli* Schaudinn 1903.)

Form oval or pyriform (Fig. 5163); diameter from 0.0075 to 0.05 mm.; nucleus distinct in life, spherical, 0.002, usually 0.003–0.007 mm. in diameter, with heavy nuclear membrane and many small nucleoli. Ectosarc not distinct save in pseudopodia, where it is conspicuous, everywhere less refractive than endoplasm. Pseudopodia rare, usually one or two, broadly lobed and heavy (Fig. 5164). Endosarc finely granular, with one or several non-contractile vacuoles, and many objects ingested as food; such are leucocytes, erythrocytes, eosinophilia, bacteria, starch granules, fæcal particles, epithelial cells, etc. (Fig. 5165). The digestion of erythrocytes is accomplished without excretion of any pigment masses.

Reproduction in the human intestine by simple division and by schizogony, with the formation normally of eight daughter cells. In fission the nucleus undergoes amitotic division, while in schizogony complicated nuclear changes are seen with the elimination of a portion of the chromatic substance. As a preliminary step to encystment all foreign bodies are extruded from the protoplasm, which thus becomes clear and transparent. These cysts, first discovered by Grassi, were carefully studied by Casagrandi and Barbagallo. They constitute the means of transmitting infection, as has been determined experimentally, first by Calandruccio who swallowed such encysted forms and found the developed amœbæ twelve days later in the fæces. The normal seat of this species is the upper region of the colon, and the vegetative forms appear in the fæces only when the latter are semi-fluid by reason of disease or of the administration of medicaments. The cysts which are so characteristic as to be confused with nothing in the fæces are capable of further development only when they contain eight nuclei. Other cysts have been determined experimentally by Schaudinn to be incapable of development, even though they actually constitute the major part (eighty per cent.) of those evacuated. In old dry fæcal matter only the forms with eight nuclei are present, and in the colon of the next host eight small amœbæ are formed by division of the protoplasm and emerge to begin a new infection and a new vegetative period.

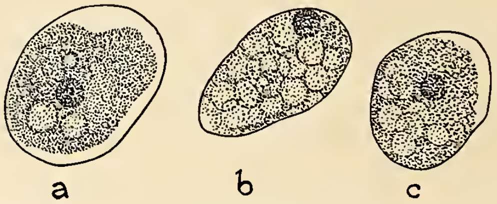

FIG. 5165.—"*Amœba coli*," from Dysenteric Intestine, more or less filled with Erythrocytes; Nucleus also visible. Magnified. (From Doflein after Roemer.)*

This species occurred in East Prussia in fifty per cent. of the cases examined; in Berlin the number found infected was 1:5, and on the Adriatic coast 2:3. The exact distribution of this species has not been further worked out, though the numerous reports lead one to believe that it is a cosmopolitan species.

Grassi was the first to identify the species from the normal human canal, and Schuberg confirmed this by a considerable series of cases. Casagrandi and Barbagallo demonstrated conclusively that it does not possess pathological characteristics, and quite recently Schaudinn in an exceedingly extensive and careful investigation showed the existence of two very similar species, hitherto generally confused, one of which, that under consideration, is a harmless commensal, and the other to be considered next a dangerous parasite. The first lives in the human host in health and is widely distributed; it multiplies excessively in various intestinal disturbances, and is brought to the exterior in fæcal matter by any conditions which produce fluid or semifluid discharges from the canal. It can indeed coexist with the following species, which is pathological in the extreme. The present

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* In advance of the appearance of Schaudinn's figures it did not seem advisable to do more than quote the name given in the original from which these cuts were taken.

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species was first carefully studied by Casagrandi and Barbagallo, and is easily recognized from their account. In the majority of cases reported, however, it is difficult to say which form was under examination, although it is probable that in many of them both species were studied and the description contains features characteristic of both. This is the case with the full and valuable account given in Vol. I. of the HANDBOOK. (See *Amœba coli.*) To this admirable review of the subject have been added here only such features as aid in distinguishing the two recently differentiated species.

Entamœba histolytica Schaudinn 1903. (Syn.: [?] *Amœba dysenteriæ* Councilman and Lafleur 1891.)

In many general features like *E. coli*, often occurring together with the latter, and heretofore generally confused with it, yet distinguishable by the following features: Ectoplasm well developed and present as distinct plasma zone, more highly refractive than the endoplasm, viscous in consistence and glass-like in appearance. Nucleus rarely visible in life, almost homogeneous; little refractive, poor in chromatin, usually with a single nucleolus in centre, and with very delicate nuclear membrane, if indeed any is present. Reproduction by division and budding, the latter often multiple, and both following amitotic nuclear division. Cysts with eight daughter cells never found. Resting stages are formed when the fæces grow firmer; the progress of their formation begins by the rejection of chromatin from the nucleus until the entire plasma is filled with chromatin masses, and the nucleus itself degenerates and is absorbed or thrown out. The chromatin masses collect in the peripheral zone of the plasma and come to lie in ectoplasmic hillocks, which develop to free spherules on the surface of the cell. These structures measure only 0.003–0.007 mm. in diameter, and soon acquire a yellowish-brown membrane and a highly refractive semi-opaque appearance. The remainder of the amœba goes to pieces. Schaudinn was able experimentally to evoke a severe dysentery by feeding these spores to cats, and maintains on good grounds that such spores constitute the only means of producing a new infection normally. Injections per anum of the vegetative form alone produced a typical case of the disease, as Jürgens showed first.

While *E. coli* has no power to penetrate the healthy epithelium, *E. histolytica* is able to enter anywhere and force its way through. In this process the amœbæ push the cells apart, and even force them free from the layer. These features were first correctly described by Jürgens, who gave a full and accurate account of this species. His discoveries on the cat have been confirmed by the observations of Schaudinn on man also. The amœbæ were found in sound regions of the mucosa in the glands of Lieberkühn, could be followed on into the submucosa. Undermining of the mucosa and abscess formation follows in later stages of the malady. These investigations demonstrate clearly that *E. histolytica* is a true tissue parasite, like the Myxosporidia, and indeed the most dangerous of all Protozoa yet known, and that it is the cause of ulcerous amœbic enteritis.

Jürgens is the only author who in the opinion of Schaudinn has characterized this species in recognizable form, although the species was probably before many authors, who were unable to differentiate it clearly from the other species, *E. coli*, with which it was certainly associated in some cases reported.

The material from which the pathological species was obtained by Schaudinn came from a limited number of cases of tropical dysentery acquired in Egypt, China, and Siam. The real geographical distribution of the species is thus evidently but imperfectly known.

It is difficult to pass satisfactorily upon the specific character of the forms hitherto observed in the United States, and only two references will be made. The observations of Craig (*Medical News*, March 16th, 1901) seem to have been made on *Entamœba coli* of Schaudinn, in which the former described as "oval spots" the formation of the encysted daughter cells already well known from the work of Casagrandi e Barbagallo. The splendid monograph of Councilman and Lafleur in my opinion deals unmistakably with *E. histolytica* of Schaudinn. The description of the amœbæ is very detailed and precise, and apparently agrees minutely with the characters, such as the form, appearance, and position of the nucleus, advanced by Schaudinn to separate the pathogenic *E. histolytica* from the harmless *E. coli.* The absence of any reference by such careful observers to the formation of cysts, which is easily observed in *E. coli*, must be regarded as confirmative evidence of the presence of the other species. If this opinion with regard to the identity of the forms proves to be correct, the specific name given by Councilman and Lafleur will have to be used in preference to the later form given by Schaudinn and the species will be known as *E. dysenteriæ* (Councilman and Lafleur 1891). Although illustrated by very inadequate figures, the pathological lesions caused by this species are described by these authors with great fulness and care, and anticipate very largely the work of Jürgens, to which Schaudinn accords such well-merited praise.

The following forms included under the generic name *Amœba* are classified thus rather tentatively, as our knowledge of the life history at least is too limited to allow of greater precision. Probably some at least are related to the species just described if not identical with them.

Amœba Miurai Ijima 1898.—Normally isolated individuals (Fig. 5166), adhering in conglomerate-like clusters only when dead or dying. Living specimens, spherical or ellipsoidal, having at one pole a small rounded protuberance or villous knob, which is closely set with fine pseudopodia. Diameter 0.015–0.038 mm. Villous knob papilliform or hemispherical, 0.01 mm. in diameter at base, but capable of entire retraction at times, or the fine pseudopodia may be entirely withdrawn. Nucleus round, oval, or reniform, 0.008–0.015 mm. in diameter, two or three being found in the single cell as often as one. Ectoplasm visible only in villous knob; endoplasm finely granular with one to several conspicuous non-contractile vacuoles and minute oil-like corpuscles.

This form was found by Miura and described by Ijima. It occurred in the serous fluid accumulation of peritoneal and pleural cavities in a female, twenty-six years old, who died from peritonitis and pleuritis endotheliomatosa. The amœbæ were absent at first from the fæces, but made their appearance two days before the patient's death, concomitantly with hemorrhage in the intestine. Living and dead individuals were found together in the freshest serous fluid under rigid precautions against injurious influences, and this is regarded by Ijima as evidence of the abnormal occurrence of the parasite. It has not been reported since then, and is explained by some authors on the basis that the supposed amœbæ were only "exudate cells." Lühe states that this is unquestionably the case.

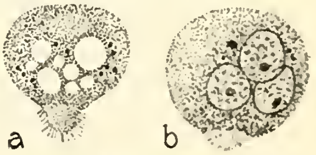

FIG. 5166.—*Amœba Miurai.* *a*, Living; *b*, from specimen preserved in acetic acid. × 500. (After Ijima.)

A considerable number of so-called amœbæ have been reported from various organs in man, and usually pathogenic characteristics have been attributed to them. They are known mostly from single records of their occurrence, and often lack both name and recognizable description. It has been suggested that they are commensals, and of secondary importance. It is equally probable that some at least are occasional or accidental parasites, and devoid of general importance in human pathology. Owing to the general uniformity of structure in this group all but the most careful descriptions are worthless for future study and comparison with other species. A few of the best accounts of these uncertain forms are noted here for reference.

Amœba Kartulisi Doflein 1901.—Diameter 0.03–0.038

mm. without distinct ectosarc and endosarc. Plasma coarsely granular, with very small nucleus (or nucleolus?), demonstrable only by staining. Movement more rapid than in *Entamœba coli*. Usually only one or a few pseudopodia, long, digitate and rapid in formation. Reproduction not observed.

This species was found by Kartulis in Alexandria, where it occurred in an Arabian, in a tumor the size of an orange, on the right mandible. In the thick pus and on fragments of extracted bone the amœbæ occurred together with numerous bacteria. They had been feeding on blood and pus corpuscles. Although apparently distinct from *Entamœba coli*, Doflein inclines to regard their connection as not impossible, and views as even more probable this interpretation of the amœbæ from an abscess in the oral cavity reported by Flexner. These were described as larger than leucocytes, with granular vacuolated plasma and a nucleus demonstrable only with some uncertainty. Although in both these cases the presence of *Entamœba coli* in the host had not been shown by any antecedent dysentery or fæcal examination, it has already been stated that this species may be present in the normal intestine, and its occurrence outside the canal in abscesses is abundantly demonstrated by other cases. It is less probable this form may have been *Entamœba histolytica*, though the description is not distinctive, as the absence of lesions in the canal can hardly be explained if the pathogenic species was present.

Amœba urogenitalis Baelz 1883.—Diameter 0.022–0.05 mm. Plasma coarsely granular, containing one or several nuclei, excretory products, and erythrocytes. Movement slow, by formation of short pseudopodia. Encysted forms possibly occur.

Originally found in numbers in the bloody urine and vaginal mucus of a Japanese female, twenty-three years old, who shortly before her demise from tuberculosis manifested hæmaturia with strong cystic tenesmus. (*Cf.* Vol. I., p. 233, HANDBOOK.) Similar cases have been reported by many authors. In Jürgens' case chronic cystitis was associated with small mucous cyst filled with amœbæ; these were also present in the entire vagina. The descriptions are scanty and do not render a differentiation between these forms and *Entamœba coli* and *E. histolytica*, either structurally or clinically easy at present. Pathogenic characteristics are certainly not distinctly shown, and in so far this case belongs more probably to *E. coli* if to either. Better knowledge of the species and more careful examination of the reports of previous observers may make it possible to refer some such cases to a definite species; but many will always remain uncertain.

Amœba buccalis Sternberg 1862; *Amœba dentalis* Grassi 1879; *Amœba gingivalis* Grassi 1849.—All these species were discovered in tartar scraped from the surface of human teeth. They have not been reported a second time, and Celli and Fiocca state specifically that they have failed to find amœboid organisms in the oral cavity. Grassi himself suggested the possibility of confusion with salivary corpuscles.

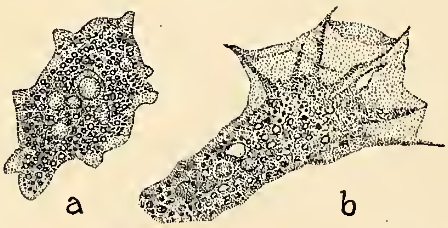

FIG. 5167.—*Leydenia gemmipara; a*, at rest; *b*, in movement. Magnified. (From Doflein after Schaudinn.)

Amœba pulmonalis Artault 1898.—In an examination of the contents of a large pulmonary cavity a small number of amœbæ were found among the leucocytes, which were distinguishable by firm contour, much finer and more uniform granulation, and a distinct nucleus or vacuole. In appearance like the epithelial cells found in sputum they manifested changes in form and position through the slow formation of pseudopodia. They were also more highly refractive, and resisted methylene blue or fuchsin longer than leucocytes, but when preserved they stained readily and were indistinguishable from the latter. Despite the conjectures of the discoverer their real nature remains entirely unknown.

Leydenia gemmipara Schaudinn 1896.—Irregularly spherical or polygonal in form when resting (Fig. 5167, *a*), surface with prominent verrucosities. Ectosarc and endosarc not distinctly limited, but pseudopodia more hyaline than the opaque body with numerous highly refractive yellowish granules. Diameter of body, 0.003–0.036 mm. Nucleus single, spherical, distinct in life, and in the preserved specimen regularly one-fifth the diameter of the body; movement very slow, produced by formation of a broad, hyaline lamella at the anterior margin; streams of granular endosarc extend to the margin of this lamella (Fig. 5167, *b*), and may even project beyond it as pointed pseudopodia. The endoplasm contains granules, crystalline bodies, interpreted as excretory, and numerous vacuoles which increase in size toward the centre. A pulsating vacuole is present and contracts at intervals of about fifteen minutes.

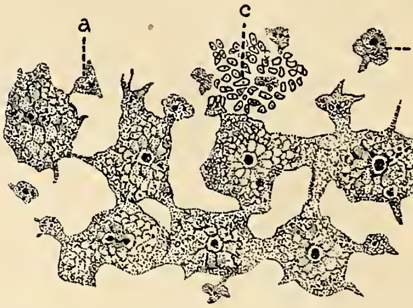

FIG. 5168.—*Leydenia gemmipara. a, b, c*, Young individuals formed by gemmation. *n*, nucleus. Magnified. (From Doflein after Schaudinn.)

Two or more individuals frequently unite without fusion of the nuclei, and plasmodia are formed by the union of many single individuals. Both division and gemmation occur. In the former the size of the resulting amœbæ may be very different, but is always proportional to the size of the nuclei (5:1). The nucleus divides directly, and the bud which originates as a protuberance from the surface of the amœba gradually works free and becomes an independent individual, which may at once undergo multiple division, giving rise to a mass of small spore-like forms (Fig. 5168).

Many years ago Lieberkühn observed in ascites fluid associated with malignant tumors peculiar cells; and similar structures were seen later by others. In 1896 Leyden and Schaudinn, on the basis of an exact investigation of these bodies in a particular case, determined them as a new parasitic rhizopod. Leyden had found them in the ascitic fluid of two patients in whom positive evidence of gastric carcinoma and of tumors in the peritoneal cavity was furnished. The amœbæ appeared in numbers in fluid drawn off from the cavity, and could be kept alive in fluid preserved several days under aseptic conditions. Schaudinn studied the amœbæ carefully and pronounced them to be unmistakably parasitic forms. Some later critics have inclined to reject this view, and regard them as descendants of the human tissue cells or pathologic neoplasms. L. Pfeiffer especially has maintained that similar large amœboid cells ("exudate cells") occur in variola, vaccinia, varicella, herpes zoster, etc., and yet the contractile vacuole, peculiar nuclear structure, and reproductive processes of *Leydenia* indicate unmistakably an independent organism, as well as many other features in which it resembles various related free-living forms.

Originally Leyden and Schaudinn were inclined to connect this form with carcinoma, but expressed no positive opinion on this point. Unfortunately it has not been studied by subsequent investigators, and in fact has been found but twice since then, although often sought for under similar circumstances. Recently Schaudinn has advanced the view that this form is probably an accidental commensal.

The class of the Mastigophora includes a great variety of organisms, having in common hardly more than the possession of vibratile organs of locomotion known as flagella, which by greater length, lesser number, and type of movement are easily distinguishable from cilia. The group shows relationships in many directions, and affords an almost unbroken line of transition to forms which are typically plant organisms. Here, again, as in the last class (Sarcodina) the uniformity of structure, coupled with an even smaller average size and very insufficient acquaintance with the life history, render it difficult to speak positively regarding many of the organisms. Of the sub-classes, which are founded upon the number and arrangement of the flagella, the character of the cell body and general habits of life, only one, Flagellata, is of importance here, as the others contain no parasitic forms.

The general form of the body, the number and position of flagella, and the precise method of reproduction serve to distinguish in the sub-class Flagellata five orders. Only two of these embrace human parasites and demand consideration here,· namely: Protomonadina and Polymastigina.

The Protomonadina are small forms, often tending to form colonies. They have at the anterior end one flagellum, two similar flagella, or two or three dissimilar flagella. In many parasitic species an undulating membrane accompanies a single flagellum. Doflein gives the following key for the determination of those families which include parasitic species:

1. A single flagellum on anterior end 2
   Two flagella on anterior end............Bodonidæ
2. An undulating membrane along the side of the body..........................Trypanosomidæ
   No undulating membrane present. . Cercomonadidæ

Cercomonas.—The species in this genus are rather uncertain. Many forms have been assigned to it which later studies have shown to belong to other genera. Confusion is possible both with plant organisms and with mere developmental stages of other groups. The species are small and colorless; in form round or oval, with a very large flagellum, which is projected ahead in locomotion. Many of the forms reported from the human body and assigned to this group are imperfectly known, often found but a single time, and in many cases probably pseudoparasites of various degrees. One or two of the more distinct forms need brief mention here.

Cercomonas hominis Davaine 1854.—Body pyriform, pointed posteriorly, with single flagellum at anterior end. Length 0.01–0.012 mm. Movement rapid, capable of attaching themselves by posterior tip. Smaller variety 0.008 mm. long.

Found in the dejecta of a cholera patient, the smaller variety in typhoid dejecta. Various later reports may be assigned to this species, including that of Lambl in 1875, which has often been erroneously identified as the same as the species described under the same name by this author in 1859. The latter will be discussed under its present name of *Lamblia duodenalis.* Some authors have assigned the former species to *Trichomonas,* forgetful of the fact that it possesses but a single flagellum.

It would be hazardous to assert that all typical cercomonads thus far described from the human host fall unquestionably into the limits of a single species; yet in the absence of contradictory evidence they may for practical purposes be considered as such. These forms have been found in the alimentary canal, the bronchial system, in pleural exudate, and in an *Echinococcus* cyst. Encysted forms have also been described. All investigators have not been equally careful to demonstrate the intestinal origin of such forms as were found in fæces, and which may have been due to secondary contamination of the fæcal material. Among numerous records only those of Councilman and Lafleur and of Dock concerning the occurrence of such forms in this country need be mentioned.

Monas pyophila R. Blanchard 1895. (Syn.: *M. pyophyla* Neveu-Lemaire 1902.) Form similar to large spermatozoa, 0.03–0.06 mm. in diameter of body, with long filament from rounded pole, resembling a flagellum, yet capable of retraction when the form becomes nearly spherical. Outside a cuticular (?) layer, which extends through the body in partitions, dividing it into three regions. Movement rapid, accompanied by change of form.

Found by Grimm in sputum and pus of abscesses in lung and liver of patient in Japan.

The Trypanosomidæ are parasitic forms with a chief flagellum directed anteriad, usually two-edged, with more or less of a spiral twist in the body, and with one edge of the body provided with an undulating membrane. The numerous species are hæmatozoa in vertebrates, though some live in the body cavity and alimentary canal of both vertebrates and invertebrates. Those forms of importance here all fall in the genus *Trypanosoma* s. str. Much difference of opinion prevails as to the number of species and their limits. Most of them are very poorly known, although several so-called species were discovered as much as sixty years ago; indeed of no form is even an approximately complete account of the life history at hand. Various species are recognized in various parts of the world as the cause of specific diseases among domesticated animals, which have assumed economic importance of the first rank. The most prominent of these are the following, together with the range and host of each species listed.

Trypanosoma Lewisi, in rats and (?) the hamster, reported from Europe, Asia, Africa, and North America, and causing at times fatal epidemics.

Trypanosoma Brucei, in cattle, horses, mules, and wild animals, gives rise to the *nagaña* or Tsetse-fly disease in Africa south of the Sahara.

Trypanosoma equiperdum, in horse, ass, and other domesticated species by inoculation, causes *dourine* in the circum-Mediterranean region.

Trypanosoma Evansi, in mammals, especially domestic, where it causes the *surra* in India, China, Burmah, and the Philippines.

Trypanosoma equinum, in horses, causing *mal de caderas* in South America.

Trypanosoma Theileri, in cattle, producing the *galziektè* in South Africa.

Although but little evidence is at hand, the weight of opinion is against any possibility of the transmission of these species to man.

Some structural features of the genus *Trypanosoma* s. str. need brief mention. The lancet-shaped body (Fig. 5169, *a*) shows a finely granular endoplasm and a distinct though very delicate hyaline ectoplasmic layer. The single flagellum arises near the posterior end in connection with the highly refractile granule variously denom-

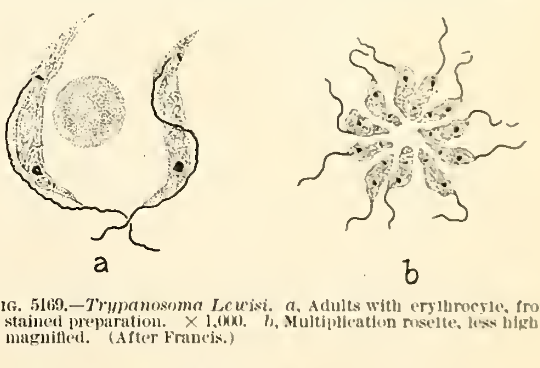

Fig. 5169.—*Trypanosoma Lewisi.* *a*, Adults with erythrocyte, from stained preparation. × 1,000. *b*, Multiplication rosette, less highly magnified. (After Francis.)

inated centrosome, micronucleus, and nucleolus. The flagellum continues along the body as the thickened outer margin of the undulating membrane, and projects free from the anterior end of the animal. The prominent nucleus occupies a slightly different position in different species; it is rich in chromatin and stains deeply in prepared specimens.

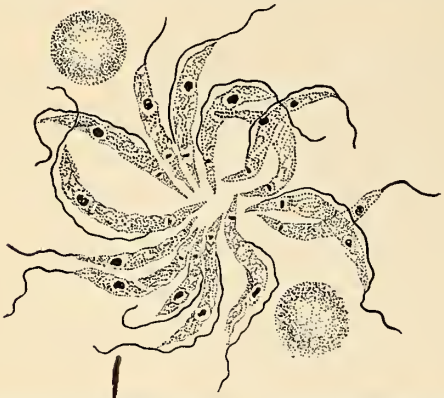

FIG. 5170.—*Trypanosoma Lewisi.* Auto-agglutination. Highly magnified. (After Francis.)

Three types of reproduction are imperfectly known: a typical longitudinal division, a budding said by Senn to be more common, and a segmentation or multiple division into numerous spores (?) arranged in rosettes (Fig. 5169, *b*). The rosette formation is regarded by some authors as the result merely of the successive division of an ordinary individual of the species. These rosettes of enormous size, embracing several thousands of individuals, occur characteristically in cultures of *Trypanosoma Lewisi* (Fig. 5170). Such cultures have been recently successfully obtained by McNeal and Novy in a strictly pure form, and have been maintained for somewhat over a year. The great importance of this step for the study of the pathogenic activity of the organism and of the possible protective measures in combating the disease is evident at once. The species found in man is

Trypanosoma gambiense Dutton, 1902. (Syn.: *T. hominis* 1903; *T. Nepveu* Sambon 1903.) Length in stained preparation (Fig. 5171), including flagellum 0.018–0.025 mm., width 0.002–0.0028 mm. Free part of flagellum about one-third of total length. Anterior end attenuated along flagellum, posterior end roughly conical, very blunt. Oval macronculeus just anterior to centre of body, occupying entire width of animal. Near posterior end dark spot, the micronucleus (the centrosome of Laveran and Mesnil), and just anterior to it a large vacuole well marked. The flagellum ends at the upper edge of this vacuole. The first record of the occurrence of a trypanosome in man is said to have been published by Nepveu in 1891, and again in 1898. The description given, however, is too scanty to admit of any opinion regarding its general character, though many are inclined to interpret it as a member of the genus *Trypanosoma.* This species was discovered in 1901 by Dutton in the blood of an Englishman in government employ on the Gambia River. The case was under observation some time, namely, until the patient died in January, 1903, and manifested the following clinical features: general weakness, irregular lapsing fever lasting one to four days with apyrexial periods of two to five days, some œdema, injection of the skin, enlargement of the spleen, constant frequent pulse, and hurried breathing. These symptoms were associated with no definite organic lesions.

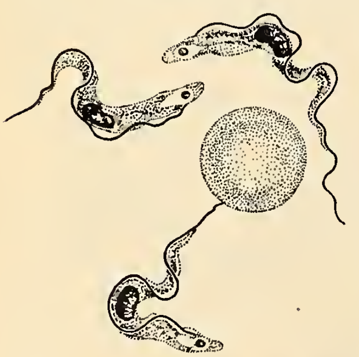

FIG. 5171. — *Trypanosoma gambiense,* with erythrocyte, drawn from stained preparation. × about 1,900. (After Dutton.)

In many prepared slides and fresh blood mounts there were found no malarial organisms. The number of trypanosomes present varied from one to fifteen, but in apyrexial periods none were detected in the blood. The parasite usually progressed with the flagellum in front, but occasionally reversed direction for a short distance. In slow progression wave-like motions start in the flagellum and are communicated to the undulating membrane; in rapid motion the body rotates on its longitudinal axis so that the undulating membrane appears as if spirally arranged. In one instance a mononuclear leucocyte was observed which had partially engulfed a trypanosome, only the flagellum and a small part of the anterior end of the body remaining free.

In films of blood taken from a child three years old the parasite was discovered again and associated with it malarial organisms. Annett points out that the chronic character of the disease, the rarity of the parasites, their apparent absence at long periods from the peripheral circulation, and the occasional rise in temperature favor confusion with malaria in diagnosis.

Later further cases of the malady have been identified by Dutton, Manson, and others, making in all six cases on the Congo River and seven on the Gambia, which are nearly equally divided between natives and Europeans. It is thus evidently not rare in tropical Africa, as Dutton found his seven cases in somewhat more than one thousand examinations in Senegambia. Two investigators seem to have identified it in India also, and it may be expected to occur in other countries as well, as do the corresponding affections of domestic animals.

A final most recent contribution of great importance to this subject has been made by Castellani, who found *Trypanosoma* in the cerebro-spinal fluid of natives afflicted with the so-called "sleeping sickness." This hitherto entirely unexplained disease, epidemic in certain regions of Africa, attacks only natives, and is characterized by a drowsy condition culminating in deep coma, with an all but universally lethal outcome in from three to twelve months. Hyperæmia of the arachnoid vessels is the only known pathological feature. Bacteriological investigations have remained without result, and the theory of Manson that the cause of the malady lay in the presence of *Filaria perstans* has already been referred to in another article (*Nematoda*). Castellani's hypothesis has been greatly strengthened by the communication of Bruce to the Royal Society that *Trypanosoma* was present in the cerebro-spinal fluid in every one of thirty-eight cases of sleeping sickness investigated in Uganda, and occurred also in the blood in twelve out of thirteen cases tested on this point.

This species, which has been named *Trypanosoma Castellanii* (see Sambon in *Journal of Tropical Medicine,* July 1st, 1903), closely resembles *Trypanosoma Brucei,* but is said to differ in the following morphological peculiarities: a more or less rounded anterior extremity (posterior extremity of most authors, but this species moves with the more rounded extremity foremost), the centrosome outside the vacuole and much closer to the extremity, the larger vacuole placed before (?) the centrosome, the longer free portion of the flagellum and fewer granules at the posterior extremity.

The transference of the parasite is probably due to some blood-sucking insect, as has been demonstrated for other species of *Trypanosoma;* and in the case of the sleeping sickness, *Glossina morsitans,* the Tsetse fly has been declared responsible by Brumpt. In an illuminating discussion of the subject he shows that the disease is extraordinarily widespread among fishermen on the Congo, and almost unknown among people in the vicinity, who yet do not visit the stream. This accords with the habits of the Tsetse fly, which occurs on the river in immense swarms and is not found a short distance away from it. The freedom from this disease enjoyed by the whites can only be explained on the basis of present knowledge as a type of racial immunity. Recent observations, however, serve to arouse suspicion as to the correctness of the assumption itself.

Although the morphological differentiation of the various species of *Trypanosoma* is difficult, not to say impossible at present, there are sufficient grounds in the clinical features of the diseases caused by them, and in other physiological data, such as the immunity of various host species to certain forms, to justify the acceptance of their specific distinctness. One may well recall the earlier view, that only one form of malarial organism existed, and may find in the transport by *Anopheles* of different species of *Plasmodium* a case parallel to that of the Tsetse fly. Whether the latter host affords the opportunity for the development of a special phase in the life cycle of the trypanosome is as yet purely a matter of conjecture.

The family of the Bodonidæ would not call for any discussion here were it not for the frequence with which certain species have been assigned a rôle as parasites of man. The form which has most frequently been mentioned in this connection is

Cystomonas urinaria (Künstler 1883).—(Syn.: *Bodo urinarius* Künstler 1883; *Cystomonas urinaria* Blanchard 1886; *Plagiomonas urinaria* Künstler of Braun 1895.) Shaped like a beet root (Fig. 5172), 0.01 mm. long, 0.004–0.005 mm. broad, the broad anterior end notched, the posterior end in the form of a long slender filament. Nucleus anterior; two similar flagella originate from anterior notch.

In 1856 Hassall described an infusorian which he had observed in alkaline urine that had stood some time open to the air. It was subsequently found in fifty samples of urine from various sources left open similarly, sufficient proof of the contamination. In 1883, however, Künstler reported a form under the same name from fresh urine, which was accordingly attributed to the urinary passages. Blanchard held this to be in reality a new species and renamed it, bringing it in connection with a form described by Salisbury as *Trichomonas irregularis*. Braun regards the latter as rather *Tr. vaginalis*, and distinct from the former, for which he inclines to the view that it was actually a contamination. This is the more probable, as Th. Barrois found many flagellates in "freshly voided" urine in Lille, when subsequent examination yielded no trace of these parasites in urine of the same patients. Evidently the presence of such forms in human urine is beyond question, but their origin from the human urinary passages is yet to be demonstrated. That all such cases require the most searching examination is evinced by a recent experience of my own, in finding objects which were probably much contracted rotifers in preparations made from "absolutely fresh" urine.

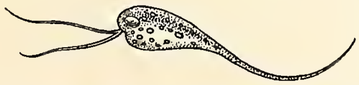

FIG. 5172.—*Cystomonas urinaria*. Magnified. (From Braun, after Künstler.)

The order Polymastigina includes small forms, always non-colonial, with three similar flagella, or with four to eight flagella dissimilar in size and differently located. Two families contain parasitic forms and are distinguished as follows:

Body with three or four flagella, all at anterior end . . . Tetramitidæ

Body with four to six flagella on anterior end; posterior end either with two flagella, or prolonged into one to three lobes . . . . Polymastigidæ

In the Tetramitidæ are included species of elongated form with usually pointed posterior end. They have no cuticula, or pellicle, hence may also manifest amœboid movements. One of the flagella may be represented by an undulating membrane. Only one of the genera, *Trichomonas*, embraces human parasites. The diagnosis of the genus may be given briefly as follows:

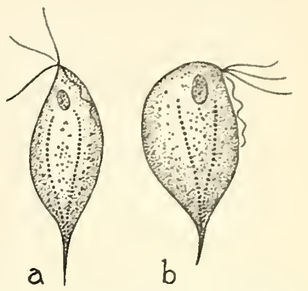

FIG. 5173. — *Trichomonas vaginalis*. *a*, From osmic-acid preparation; *b*, living. Magnified. (After Blochmann.)

Trichomonas Donné.—Generally pyriform, with anterior end rounded or almost pointed. Posterior end moderately pointed. Nucleus near anterior end, vacuoles near posterior, no contractile vacuole. Either three equal flagella from anterior tip, and also an undulating membrane (*Trichomonas* s. str.), or with three equal flagella directed anteriad, and one much longer extending posteriad from the same point of insertion (sub-genus *Trichomastix*).

Trichomonas vaginalis Donné 1837.—Body very mobile, usually pyriform or spindle-shaped (Fig. 5173), with posterior end sharply pointed and anterior end more or less rounded. The posterior tip is half as long as the rest of the body. Total length 0.015–0.025 mm At anterior pole originate three flagella (four according to other investigators) of equal length, and an undulating membrane which winds spirally about the body to the base of the posterior tip. Plasma finely granular, nucleus near anterior end; posterior to it according to Blochman two longitudinal rows of prominent granules. Division has been reported; encystment is as yet unobserved.

This species is present in females where vaginal catarrh is associated with an acid reaction of the secretion. It has been found in girls of six or seven years and in aged women; and other conditions affect its presence as little as age save that menstruation, alkaline injections, or other conditions which alter the reaction of mucus result in its disappearance temporarily at least. A low temperature (15° C. or less) is also fatal to its existence. Dock and others have demonstrated the presence of this species in the urine of males; the infection doubtless resulted from intercourse and was made possible by an already abnormal condition of the male urethra, as was shown in the cases under discussion. Dock was unsuccessful in infecting guinea-pigs and dogs, and the means of transference from one female to another is unknown. According to Hausmann thirty to forty per cent. of females are infected. The parasites are easily demonstrated in the vaginal mucus, where they move slowly about among epithelial fragments and mucous corpuscles; but for successful demonstration the urine must be examined as soon as passed. Whether their relation to the vaginal catarrh is primary or secondary remains entirely undecided.

*Trichomonas intestinalis** (R. Leuckart 1879).—(Syn.: *Protoryxomyces coprinarius* Cunningham 1881; *Monocercomonas hominis* Grassi 1882; *Cimænomonas hominis* Grassi 1882; *Trichomonas hominis* Grassi 1888; *Cercomonas coli hominis* May 1891; *Monocercomonas hominis* Epstein 1893.)

Very similar to *Tr. vaginalis* but smaller, measuring 0.004–0.015 mm. in length and 0.003–0.004 mm. in breadth, without rows of granules; posterior end more sharply set off and measuring only one-third the length of the body. Three flagella, the free edge of the undulating membrane has sometimes been interpreted as a fourth. Otherwise as in *Tr. vaginalis*, although the species has not been carefully investigated. Kruse and Pas quale observed groups of individuals which may have arisen by division. Before copulation this species loses its flagella and creeps about with bluntly lobose pseudopodia. This species is ordinarily identified as the *Cercomonas hominis* of Davaine (1854) and the *C. intestinalis* of Lambl (1875), but recent studies have demonstrated the individuality of this from the two cited. There also is a tendency at present to reduce this form to *Tr. vaginalis,* with which it agrees closely, and only an exact study can decide the question. In the uncertainty I regard it as more practical to retain both species, though they are at least closely related.

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* This form of the name is probably incorrect, but as the synonymy is badly confused I have retained it pending revision by some specialist.

Tr. intestinalis parasitizes in the anterior and middle regions of the human alimentary canal, and has been repeatedly found in various parts of the world. It occurs also in the oral cavity in decaying teeth, where it nourishes itself on micrococci. It has been reported also frequently from diseased conditions associated with diarrhœa, such as typhoid, cholera, intestinal catarrh, gastric carcinoma, and once in pulmonary gangrene. The species lives only in fluids of an alkaline reaction. Its occurrence in the dejecta of healthy adults has been taken to indicate a commensal rather than a parasitic habit; but it at least multiplies rapidly in connection with morbid processes, and this may exercise an important influence on the progress of the disease. An etiological significance cannot, in the present state of knowledge, be attributed to this species; yet the experiments of Epstein showed that an infection is apparently produced by drinking-water and followed by diarrhœa in children. Experimental infection of animals has not yet succeeded, and the presence of this species in the oral cavity, both in health and in disease, points to possible transport of unknown encysted forms by the air.

Some accounts referred to supposable new species more probably concern this. Such are the forms described by Steinberg from the oral cavity as *Tr. elongata, Tr. caudata, Tr. flagellata,* as well as perhaps also *Cercomonas biflagellata,* together with the *Tr. pulmonalis* of Schmidt and Artault from sputa or contents of a pulmonary cyst.

The family Polymastigidæ contains small biaxial or bilateral forms with two or three flagella on either side or near the anterior end, while the posterior end is lobed or provided with two further flagella. Only one genus contains human parasites.

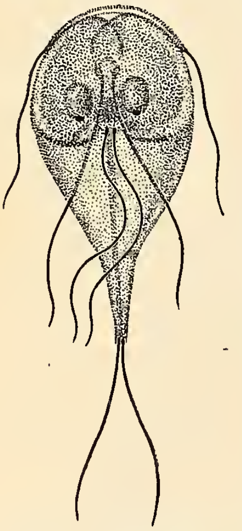


FIG. 5174.—*Lamblia duodenalis,* Living, from Rabbit Intestine. Magnified. (Combined sketch. After Metzner.)

Lamblia Blanchard.—At anterior tip one flagellum on each side, and near the centre two on either side; posterior end with two additional flagella. A concave sucking disc (?) on ventral surface near anterior end. Nucleus dumbbell shaped.

Lamblia duodenalis (Davaine 1875).—(Syn.: *Cercomonas intestinalis* Lambl 1859, nec 1875 nec Perty 1852; *Hexamitus duodenalis* Davaine 1875; *Dimorphus muris* Grassi 1879; *Megastoma entericum* Grassi 1881; *M. intestinale* R. Blanchard 1886; *Lamblia intestinalis* R. Bl. 1888; *L. duodenalis* Stiles 1902.)

Length 0.01–0.016 or 0.021 mm.; maximum breadth 0.005–0.007 or even 0.012 mm., with eight flagella nearly equal in length (0.009–0.014 mm.). In form bilaterally symmetrical (Fig. 5174). In ventral aspect it is rounded anteriorly and prolonged posteriorly into a very mobile steering tail flattened in the frontal plane. A shallow cordiform excavation of the ventral surface near the anterior end corresponds to the peristome and serves as an organ of attachment; its margin is raised and contractile, but is interrupted posteriorly; all flagella point posteriad; the anterior pair follow the margin half-way around before leaving the body; the lateral pair originate near the anterior margin in the peristome, but are bound to the body until they come to project beyond the contour of the animal; the median pair originate in the notch of the peristome margin and are vibratile through their entire length, being the chief organs of locomotion; the caudal pair are inserted at the tip of the body. The dumbbell-shaped nucleus lies dorsal to the peristome. Contractile vacuole and cytostome are wanting. Division has not been observed; the encysted form is oval, with heavy transparent wall, and measures 0.01 mm. in length by 0.007 mm. in breadth. Schaudinn reports that copulation has been observed and is followed by encystment.

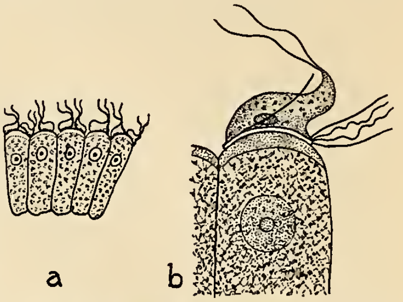


FIG. 5175.—*Lamblia duodenalis.* *a,* On epithelial cells of intestinal villus. × 370. *b,* single cell and parasite. × 1,070. (After Grassi and Schewiakoff.)

This species was first reported by Lambl from the dejecta of children in Prague. It has been reported from Germany, Italy, Russia, Sweden, Egypt, and the United States from the human host in which it seems to be a frequent parasite. It also occurs in rat, mouse, dog, cat, rabbit, sheep, and certain wild species, and is undoubtedly a common and widely distributed parasite.

Its normal seat is the duodenum or jejunum, rarely other parts of the canal, where it sits with the peristome applied to the curved outer face of an epithelial cell (Fig. 5175) on the villi. Although often in such numbers that apparently every cell is occupied, yet no pathological effect has been demonstrated to be exercised by these parasites. Normally only cysts occur in the colon and fæces, but in diarrhœic conditions the free living forms are torn loose and reach the exterior.

Grassi determined by experimental auto-infection that the cysts are the means of infection, and was unable to detect in himself any symptoms incident to the parasitism of the species. It is probable that cereals, or prepared food which becomes contaminated by rats or mice, constitute the ordinary avenue by which the infection of man is brought about.

The class Sporozoa embraces a series of groups of Protozoa of a consistent parasitic habit, which have in common the production at some point in their life cycle of numerous descendants, which are usually covered by a firm shell and accordingly denominated "spores." The enclosed young forms may be single or manifold, and in special cases the cyst wall may be lacking. These young forms always start the life cycle as cell parasites, and in all but rare cases alternation of generations appears in the course of the life history. All forms are true parasites, and all subsist only on fluid nourishment obtained by osmosis.

The class was made by Leuckart in 1879, when he brought together under the heading Sporozoa the imperfectly known and somewhat isolated groups of gregarines (Gregarinida), the psorosperm sacs of Müller (Myxosporidia), the oval or spherical psorosperms of Eimer (coccidia), and Rainey's or Miescher's corpuscles (Sarcosporidia). Later investigators have added the Microsporidia, Amœbosporidia, and Hæmosporidia, and have been able to fill up the gaps in the knowledge of the older groups, so that the association of these forms stands on a much clearer and firmer basis. This is especially true by virtue of the recent discoveries concerning the life cycles of various forms which have revealed an entirely unsuspected complexity and interrelation of the development with the parasitic habit.

In the majority of cases two types of reproduction alternate in the life history of the organism, and this alternation is associated with different factors in the biology of the parasite. The first type subserves the rapid multiplication of the parasite within the host, and is appropriately designated by Doflein multiplicative reproduction; when highly developed it will evidently transform an organism harmless because insignificant into an abundant destroyer of tissue and the exciter of disease. This may be observed again and again in the account of this group. The other type of reproduction is connected with the spread of the species, the infection of new hosts, and may be denoted after Doflein the propagative reproduction. Spore formation is here associated with all sorts of secondary or collateral structures which assist in the transport of the spores, their protection during this period, and their attainment of the new host. The morphology of the propagative reproduction constitutes the means of characterizing the major subdivisions of the Sporozoa; the multiplicative reproduction varies often widely among closely related forms.

The two sub-classes, Telosporidia and Neosporidia, are distinguished by the fact that the former produces spores only at the close of the vegetative period, while the latter do so during the entire period. For the identification of a sporozoon a vegetative stage is rarely sufficient; the form and number of the spores produced during the propagative period of reproduction are characteristic.

In the sub-class Telosporidia one may distinguish two orders on the basis of the habit of the parasites and the mode of fertilization which prevails. Thus in the Coccidiomorpha the vegetative stage is permanently intracellular, while the sexual generation may be so only transiently. The fertilization is anisogamous, *i.e.*, the fusion of differently formed gametes. In the Gregarinida on the other hand, the vegetative stage is intracellular only at the start, as the adult organism is extracellular and the sexual generation also. The fertilization is isogamous, *i.e.*, the fusion of equal and similar gametes. Under the order of the Coccidiomorpha are included forms which until recently have been treated as much more distinct. But more careful study, particularly of the life history, has shown an increasing degree of likeness until they are now included in the same order, and mutally opposed to the Gregarinida in the specific cell parasitism, and in a similar alternation of generations and of hosts in addition to the features pointed out in the outline of the system given above. The features which serve to distinguish the two sub-orders of the Coccidiomorpha are these: The Coccidia produce sporozoites encased in sporocysts, with the exception of *Legerella*, the copula is non-motile and remains in the cell. In the Hæmosporidia the sporozoites are always free, the copula is an active ookinet, and migrates to a new location before undergoing further development.

The adult Coccidia occur as parasites in epithelial cells, particularly of the alimentary canal and its adnexa, though the excretory organs, the male sexual organs, and most recently the spleen are also reported as affected. While the protoplasm of the host cell is ordinarily the seat of the parasite, there are not wanting such as occur in the nucleus itself. Only rarely is more than a single parasite found in an epithelial cell.

In form the Coccidia are uniform and constant, being spherical, oval, or elliptical, and without organs of locomotion of any sort or organs of attachment. Their size is regularly insignificant. A noteworthy characteristic is the absence of differentiation into ectoplasm and endoplasm. The plasma of the cell is finely granular, alveolar, and without reserve bodies or food vacuoles. The nucleus is large, vesicular, and characterized by a single prominent central nucleolus. No contractile vacuole is present, and no further structural differentiations can be noted. The cell and nucleus increase gradually in size at the expense of the host cell, which ultimately in most cases degenerates to a mere empty membrane encircling the coccidium.

The nucleus of the now full-grown parasite undergoes multiple division, the protoplasm arranges itself in individual masses about the many daughter nuclei, and there results a stage in which a rosette of young forms (Fig. 5176) encircles a central portion of protoplasm, known as the reliquary body or residual mass. This is without nuclear matter and destined to play no further part. It is left behind, and perishes when the young forms wander out to infect new epithelial cells of the same host, and repeat the process just sketched. This is evidently the multiplicative reproduction already referred to. It serves to effect the auto-infection of the host, and is generally known as the period of asexual reproduction or schizogony. The cell parasites which undergo these changes are schizonts, while the young forms are denominated merozoites. The merozoites are capable of active movements by contraction and twistings, or with a gliding movement, in which a trail of mucus is left behind. The growth of merozoites to schizonts in the epithelial cells, the production of new merozoites, and the infection of new cells proceed often with considerable rapidity, but only within certain limits, for a new type of reproduction intervenes.

In this which regularly begins under the pressure of excessive infection of the host, the merozoites develop not to schizonts, but to forms of two sorts, which at first sight are very similar to schizonts, and but little different from each other. The one form is opaque with a richly granular plasma; the other has a clear but dense plasma. The opaque form is the female gamete, or macrogamete, and attains maturity by the rejection of a portion of its nuclear substance. The clear cell, known as a microgametocyte, undergoes multiple nuclear division. The many nuclei produced then migrate to the surface, each collects a small part of the plasma about itself, and projects as an elongated spindle-shaped structure, the microgamete or male cell, which becomes free, forms two flagella, and enters upon active locomotion. The major portion of the microgametocyte is abandoned, and subserves no further function.

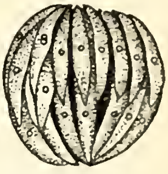


FIG. 5176.—*Eimeria Stiedæ*, Adult Schizont Completely Divided into Merozoites. Cyst formed of degenerated host cell is not represented. Magnified. (After Simond.)

The microgametes swarm about the macrogametes, and as soon as one has succeeded in entering, the macrogamete forms at once a firm membrane, which forbids entrance to other microgametes. The two nuclei unite and the act of fertilization is completed. The product is known as an oocyst, copula, or sporont, and forms the starting-point of a new period in the life cycle, which is that previously designated as the propagative reproduction. It is also known as the sexual spore-forming period, or sporogony, and in most coccidia takes place outside of the host, after the oocyst has been evacuated in fæces or urine. The steps in the process of sporogony may be outlined next in general terms (Fig. 5177).

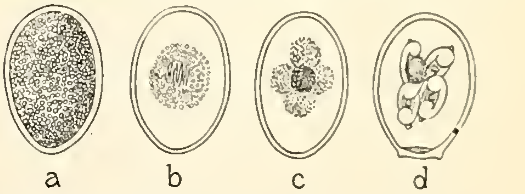
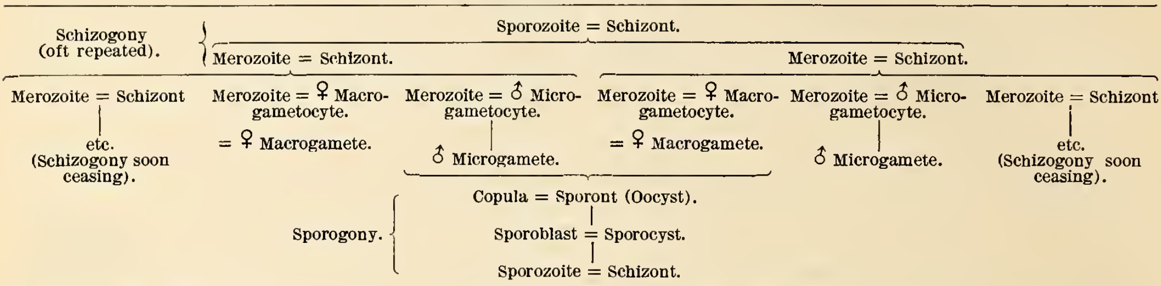


FIG. 5177.—*Eimeria hominis*. Sporogony. *a*, *b*, Oocyst; *c*, sporoblasts with residual mass; *d*, sporocysts with contained sporozoites. Magnified. (From Braun after Riek.)

The nucleus of the oocyst (*a*) divides twice, and about the four daughter nuclei the protoplasm separates into four parts known as sporoblasts (*b*), and sometimes also a residual mass of protoplasm (*c*). Each of these sporoblasts surrounds itself with a firm membrane and becomes a sporocyst (*d*), while later within each sporocyst after nuclear division two sporozoites are formed and a residual mass of protoplasm is left unused. The sporozoites are characteristically sickle-shaped or crescentic, and abandon the sporocyst when this reaches the alimentary canal of the new host, and is opened by the action of the alimentary secretions. The entrance of the sporozoites into the epithelial cells and their growth to schizonts completes the life cycle.

This typical course of development is well represented by the tabular outline given by Lühe and reproduced here. The stages connected by a single vertical line (|) are successive generations in the life cycle; those connected by the sign of equality (=) are produced by growth or metamorphosis within the single generation.

DEVELOPMENT OF EIMERIA.


Schizogony (oft repeated).
Sporozoite = Schizont.
Merozoite = Schizont.
Merozoite = Schizont.
Merozoite = Schizont
Merozoite = ♀ Macro-gametocyte.
Merozoite = ♂ Micro-gametocyte.
Merozoite = ♀ Macro-gametocyte.
Merozoite = ♂ Micro-gametocyte.
Merozoite = Schizont
etc. (Schizogony soon ceasing).
= ♀ Macrogamete.
♂ Microgamete.
= ♀ Macrogamete.
♂ Microgamete.
etc. (Schizogony soon ceasing).
Sporogony.
Copula = Sporont (Oocyst).
Sporoblast = Sporocyst.
Sporozoite = Schizont.

This general plan of development is modified in the individual species in various manner. The most striking modification is a simplification by suppression of the entire schizogonic cycle, so that the macrogametes and microgametocytes arise directly from the sporozoites which have penetrated epithelial cells.

The coccidia parasitize almost all groups of the animal kingdom, and are distributed over the entire world, although, as might be expected, the majority of reports thus far made concerning their presence come from European countries.

For the subdivision of the group Léger's proposal to use the number and form of the sporocysts and of the sporozoites has been generally adopted. The adjoined table gives a review of the common genera arranged according to Léger's scheme.

Ripe oocyst contains	Numerous sporozoites	No sporocysts. ASPOROCYSTIDEA		Legerella.
		Many sporocysts each with ..... POLYSPOROCYSTIDEA.	One sporozoite	Barroussia.
			Two sporozoites	Adelea.
			Three sporozoites	Eucoccidium.
			Four sporozoites	Klossia.
	Eight sporozoites	Two sporocysts each with four sporozoites. DISPOROCYSTIDEA		Isospora.
		Four sporocysts each with two sporozoites. TETRASPOROCYSTIDEA		Eimeria.
	Four sporozoites	Two sporocysts each with two sporozoites.		Cyclospora.

Some confusion has prevailed regarding the correct names of the various genera. The original cause of this difficulty rests on the fact that the two phases of the life cycle, schizogony and sporogony, were discovered and named separately, and that their relations as parts of the development of a single species did not become known until a much later date. All of the human parasites thus far recorded from this group fall within the limits of a genus named *Coccidium* by R. Leuckart in 1879, and this name has been generally incorporated into works on the subject. At a very recent date, however, Stiles and Lühe have independently called attention to the fact that the name *Eimeria*, introduced in 1875 by Aimé Schneider, has the right of priority, and must replace the more common form according to laws of zoological nomenclature. This is really fortunate from the general standpoint since the name coccidia has been very generally used for the entire group as well as heretofore for the genus; yet this is not in the interest of precision, and may evidently lead to serious misunderstanding. Henceforth the name coccidia can be used only in the more general sense.

The genus *Eimeria* is the best known of all. Its most important characteristic is the formation in each oocyst of four sporocysts, each with two sporozoites. A residual mass of protoplasm is always present in the sporocyst with the sporozoites, and a similar residual mass is sometimes formed in the oocyst with the growth of the sporoblasts. Of the many species assigned to this genus, the most important and better known forms which are pathologic to man and some domestic animals are included in the following key:

1. Oocyst with residual mass.... 2
1. Oocyst without residual mass........ 3
2. Oocyst oval, 33–49 μ by 16–28 μ; sporocyst spindle-shaped (rabbit, man)..................*E. Stiedæ* (Lind.)
2. Oocyst spherical or cylindrical, 15–32 μ by 11–17 μ; sporocyst oval (mouse)........*E. falciformis* (Schuberg)
3. Simple forms. Oocyst oval to cylindrical, 24–35 μ by 13–20 μ. ....*E. hominis* (Riv.)
3. Twin forms....................*E. bigemina* (Stiles)

Eimeria Stiedæ (Lindemann 1865).—(Syn.: *Monocystis Stiedæ* Lindemann 1865; *Psorospermium cuniculi* Rivolta 1878; *Coccidium oviforme* Leuckart 1879; *C. cuniculi* Raillet 1893; *Pfeifferia princeps* Labbé 1896; *Pfeifferella princeps* Labbé 1899. *Eimeria cuniculi* Lühe 1902.)

All stages are known. Oocyst (Fig. 5178) in the liver of rabbit, oval 0.033–0.049 mm. long, 0.015–0.028 mm. broad. Cyst wall heavy, smooth, with opening at one pole. The coarsely granular protoplasm completely fills the cyst, but later contracts to a spherical mass at the centre (0.017 mm. in diameter). Spore formation outside the host requires two to three weeks. The entire sphere divides into four sporocysts each with a thick covering and with a length of 0.012 to 0.015 mm. and a breadth of 0.007 mm. Two comma-shaped sporozoites are formed in each sporocyst, and a granular residual mass of protoplasm lies in the hollow between their enlarged ends (Fig. 5179). The sporozoites are set free by gastric digestion. They ascend the gall ducts, pene-

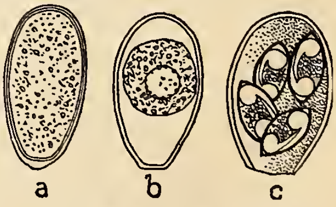


FIG. 5178.—*Eimeria Stiedæ*, Sporogony from Liver of Rabbit. *a*, Young oocyst; *b*, same with protoplasm contracted preparatory to division; c, same divided into four sporocytes, each containing two sporozoites which have already developed. Magnified. (*a*, *b*, after Leuckart; *c*, after Simond.)

trate the epithelial cells, and when fully grown measure 0.02–0.05 mm. in length by 0.02–0.039 mm. breadth. They divide into from 30 to 200 merozoites (Fig. 5176) which spread the infection. Ultimately the formation of macro- and microgametes leads to the fertilized sporont stage, the oocyst.

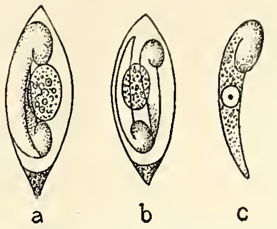


Fig. 5179.—*Eimeria Stiedæ.* *a*, *b*, Sporocysts each with two sporozoites and residual mass; *c*, a single sporozoite. Highly magnified. (From Railliet, after Balbiani.)

This species is an abundant parasite of the rabbit, in which it parasitizes in the epithelium of gall ducts and liver. According to the degree of infection sooner or later inflammation and proliferation of the epithelium lead to the formation of nodules of caseous matter, containing amid various remnants coccidia in all stages of development. These conditions may lead to severe sickness or even to the death of the host; in other cases the animal recovers as the process of schizogony appears to have distinct self-limitations. The infection is spread by the contamination of food with spore-infected fæces.

Several cases of human infection are on record. Evidently conditions favor such infection only rarely. To the four positive cases cited by Leuckart, all in Germany and Austria, Silcock has added another from London. A number of doubtful cases are also included here by some authorities. The observations of Thomas in Boston, according to which this species was found in a small cerebral tumor surrounded by bone tissue, has little to support the diagnosis in view of the normal condition of the liver and intestine, and has been universally questioned by reviewers. In any event the supposed coccidia cannot belong to this species, or any other yet reported from man, on account of their size (0.014–0.022 mm. in length). They correspond, however, in size nearly to the coccidia reported by Stiles from sheep which belong to a species as yet unnamed. More probably they are not coccidia at all.

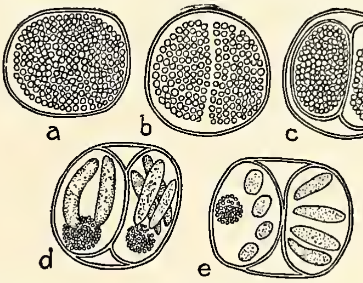


Fig. 5180.—*Eimeria bigemina*, Sporogony. *a*, *b*, *c*, Division into two masses; *d*, *e*, formation of sporoblasts with residual mass. Highly magnified. (After Stiles.)

Eimeria hominis (Riv. 1878), nec. R. Blanchard 1895.—[Syn.: *Cytospermium hominis* Rivolta 1878; *Coccidium perforans* R. Leuckart 1879; *C. hominis* Railliet 1893; *Pfeifferella princeps* (Labbé 1899) in part.]

Oocyst (Fig. 5177) 0.024–0.026, or even 0.035 mm. long by 0.0128–0.014 or even 0.02 mm. broad, plumper than those of *E. Stiedæ*, from which also they differ in the constant presence in sporulation of a residual mass of protoplasm that is said to be constantly absent in the latter species. (Compare Figs. 5177 and 5178.) Here also only three to four days are necessary to bring the division of the contents of the oocyst into sporoblasts (sporocysts).

This species, which is so closely related to *E. Stiedæ* that many authors regard them as identical, parasitizes in the intestinal epithelium of the rabbit, where it evokes serious, often fatal epidemics. Railliet and Lucet have demonstrated that infection takes place by the ingestion of ripe spores, and rapid schizogony brings about in a few days serious auto-infection involving the epithelium and Lieberkühn's glands so as to occlude the latter. The forms found in horse, goat, cattle, sheep, pig, and other wild species are usually regarded as varieties, but the considerable differences in form and size make it more probable that some at least represent distinct species.

Eimer found in two bodies examined in Berlin the epithelium of the intestine filled with coccidia, and even in large part destroyed by them. These are probably referable to this species. Other authors have reported the discovery of coccidia in human fæces at various times without furnishing data for the determination of the species concerned.

Eimeria bigemina (Stiles 1891).—(Syn.: *Cytospermium villorum intestinalium canis et felis* Rivolta 1874; *Coccidium bigeminum* Stiles 1891.)

Oocyst (Fig. 5180) 0.012–0.015 mm. by 0.007–0.01 mm. (in dog), or 0.008–0.01 mm. by 0.007–0.009 mm. (in cat), or 0.008–0.012 by 0.006–0.008 mm. (in polecat). The oocyst divides into two parts, each of which encysts and forms four sporocysts. The oocysts occur not in the epithelium, but in the central tissue of intestinal villi (Fig. 5181).

The species was first seen as early as 1854 by Fink, who, however, misinterpreted the character of the objects. It has often been confused with *E. hominis*, from which the above characteristics easily distinguish it. A case of human infection, published by Virchow in 1860, and another by Grunow in 1901, very probably belong here. The description given by Railliet and Lucet of coccidia discovered in the fæces of a mother and child who had long suffered from chronic diarrhœa corresponds well with this species in the small size of the bodies found, and is also probably referable to it. The form is evidently only an occasional parasite of man, and infection probably results from lack of cleanliness or too intimate association with pet dogs or cats. It may be that the forms discussed as varieties from different hosts actually represent different species. Stiles has found this species in dogs killed in Washington, D. C.

It is not surprising in view of the imperfect acquaintance with this group that all sorts of questionable structures should be referred to it. They are all such as have been reported from man usually in connection with some abnormal condition, and frequently also on the basis of a single occurrence. In most cases only scanty data are given concerning the supposed coccidia, and even of the best known of these problematic structures too little can be said to determine their true nature or position in the zoölogical scheme. It is best to call attention to certain of these cases briefly, in order that if possible further data should be accumulated to elucidate their real character. Perhaps the most sporozoon-like of all are bodies described by Rixford and Gilchrist from two cases studied at the Johns Hopkins Hospital in 1897; their characters so far as known do not easily permit of their classification in the coccidia (s. str.).

Coccidioides immitis Rixford and Gilchrist 1897.—(Syn.: *C. pyogenes* Rixford and Gilchrist 1897.)

Unicellular spherical bodies from 0.007 to 0.035 mm. in diameter.* So-called capsule thick, doubly contoured, enclosing a finely granular protoplasm with a clear zone [ectosarc?], 0.002–0.003 mm. wide, between capsule [pellicle?] and contents. No vacuoles seen; nucleus not demonstrated. Position of parasites usually intracellular, sometimes, however, extracellular. Sporozoites [merozoites?] ap-

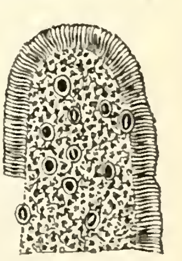


Fig. 5181.—*Eimeria bigemina* in Transsection of Villus from Intestine of Dog. Highly magnified. (After Stiles.)

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*The authors give the size of the adult (p. 229) as 15 to 27 μ; again in the diagnosis (p. 243) as 16 to 30 μ, and finally in their summary (p. 246) as 7 to 27 μ. In the second case the parasites are given as 20 to 35 μ in diameter.

proximately one hundred in a capsule, 0.001–0.002 mm. long.

Found primarily (?) in the skin, later generally throughout internal organs also. Reported from California and Buenos Ayres. All cases reported concern males of thirty to forty years of age.

In the first case the disease first appeared on the back of the neck and spread very slowly, causing death in about ten years. It was only very slightly contagious, if at all, as beyond the original sores new lesions appeared only in two spots on the patient's body, and none of those who came in contact with him are known to have become infected. Some inoculation experiments were successful, but no cultures. The cutaneous lesions resembled tuberculosis cutis in character, being the seat of genuine caseation or coagulative necrosis. Both to the naked eye and microscopically the nodules were indistinguishable from tubercles save that they contained the protozoa and did not contain tubercle bacilli. In the opinion of the discoverers this seems to indicate the power to produce toxic products which possess pyogenic properties, causing both the local lesions and general symptoms. From the fact that the whole alimentary canal and mesenteric glands remained normal throughout the course of the disease, the authors exclude the supposition that the parasites entered the system through the digestive tract. The parasites were particularly abundant in the caseous foci, and occurred in far greater numbers in the lesions of the internal organs than in the cutaneous lesions. Often these parasites were found in multitudes in giant cells. They were searched for in vain only in the membranes and substance of the brain.

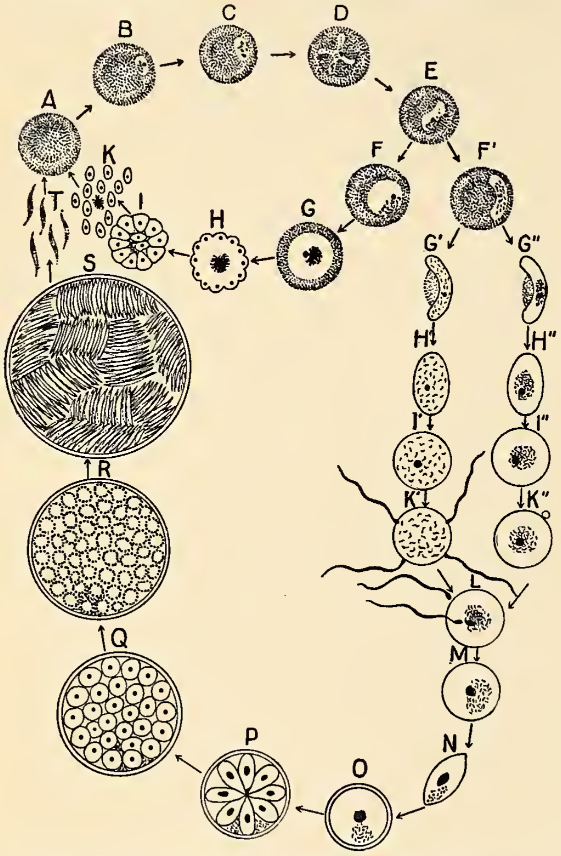

Fig. 5182.—Development of *Plasmodium immaculatum*. *A*, *E*, *G*, *K*, Schizogony in human blood; *F'*, *L*, formation of gametes and fusion of same; *M*, *S*, *T*, sporogony in mosquito. Somewhat diagrammatic. For further details see text. (After Neveu-Lemaire.)

Another case was reported by the same authors, and like the first occurred in a native of the Azores, who had been resident in California for a number of years. The disease was acute rather than chronic as in the first; and was very destructive as the patient lost both eyes, the nose, and much of the lip, and one ear in the course of three months. According to the authors the parasite was a different species, but the distinctions are insufficient to warrant a separation of the two in our present state of knowledge. The authors identify with their cases a third, reported by Wernicke in 1892 from Buenos Ayres. Wernicke gave only an incomplete description of the parasite, and regarded the cutaneous affection as a mycosis fungoides. The protozoa he found measured from 7 to 30 μ in diameter.

There are other reports of less definiteness than those just considered, and some of the questionable structures noted therein have found an explanation within recent times. Thus the psorospermcysts of Lubarsch and Ribbert, which were supposed to play a part in diseases of the urinary passages, are in reality metamorphosed nests of epithelial cells normally found in the urethra. The structures found by Künstler and Pitres in pleural exudate and interpreted by Blanchard as a sporozoon, *Eimeria hominis* R. Blanchard 1895, I have preferred to interpret as *Echinorhynchus* eggs (*Cf. Nematoda*, page 225). More uncertain still are Severi's "monocystic gregarines" from the lung parenchym of a still-born child. They are described as oval in form, exceedingly variable in size (0.003–0.03 by 0.0015–0.015 mm.), covered by a thin membrane, and either free or in epithelial cells; it is difficult to interpret them in any satisfactory manner. Some of these doubtful structures are discussed as appendices to the next sub-order, the Hæmosporidia, to which they show a certain similarity.

An error of the reverse type is that frequently made in the past of diagnosing eggs of parasites as coccidia. Thus nematode eggs have once been reported as coccidia, and eggs of trematodes many times. Were it not for the extremely small size of the structures described, the case of J. J. Thomas, noted above, concerning coccidia in a brain tumor would find its easy explanation in this same manner.

The Hæmosporidia, like the Coccidia, are characteristic cell parasites. The period of schizogony or multiplicative reproduction is passed in the blood cells, and only very exceptionally in the cells of other organs. These stages have long been known, and with them a few preparatory stages to the sporogonic cycle, although the latter have been entirely incorrectly interpreted as degenerative changes, etc. So far as is known this sporogonic cycle takes place only in the body of another host; and for the Hæmosporidia of mammals and birds this host is a blood-sucking insect in which the process of sporogony is carried out in the wall of the alimentary canal, and the sporozoites collect in the salivary glands, whence they are injected by the act of biting into a new host to start anew the schizogonic cycle. The close relationship of these forms to coccidia is evident from a study of the life history, as Doflein indicates most aptly in calling them coccidia adapted to parasitism in the blood system.

The life history may be outlined from that of the æstivo-autumnal parasite (Fig. 5182). The earliest stage of the parasite which occurs in the erythrocytes is a minute amœboid body (*A*) which increases rapidly in size, manifesting considerable amœboid activity (*B–E*). In connection with the growth of the organism particles of a black pigment matter, named melanin, are stored up in its protoplasm (*F*, *G*). The nucleus of the parasite, at first single, begins to divide rapidly when the organism has reached its maximum size and the daughter nuclei collect about the rim of the organism (*H*). Radial lines of division appear in the protoplasm (*I*), and the whole falls into a group of young germs or merozoites (*K*) about a central residual mass of protoplasm loaded with the pigment already referred to. The merozoites infect new blood cells, and the process of schizogony is repeated until conditions, as yet unknown, bring in a new set of changes, the starting-point of another cycle, the sexual phase, or sporogony.

The merozoites develop to individuals differently formed from the schizonts and of two sorts, the one finely granular and opaque (*G''*), the other hyaline in appearance with a few conspicuous pigment granules (*G'*). These forms are shaped like a bean in the species under consideration, and are those previously designated as half-moon or crescentic bodies. When fully grown they desert the corpuscle (*H'*, *H''*) assume a spherical form (*I'*, *I''*). The macrogamete extrudes a portion of the nuclear substance (*K''*) and is mature. The nucleus of the microgametocyte divides, the parts migrate to the surface and form microgametes by a small accumulation of plasma about each (*K'*), leaving a large central residual mass. These two gametes copulate, their nuclei fuse, and the product (*M*) is the starting-point of the sporogonic cycle, the sporont.

The changes leading to the perfection of the sexual cells take place only after the blood has been drawn into the stomach of the new host, the blood-sucking insect. Abnormal stimuli may, however, bring about some of the changes, as in cultures of malarial blood. The copula acquires an amœboid form (*N*) necessary for its attainment of a location within the tissue of the new host. This motile stage, which has been denominated the ookinet, is a gregarine-like organism, and penetrates an epithelial cell, where it transforms itself into an immobile spherical oocyst (*O*). After nuclear division there are formed in the oocyst numerous sporoblasts (*P*, *Q*), which, however, never acquire a heavy membrane, *i.e.*, never become sporocysts as in the coccidia. Each sporoblast gives rise to a large number of sporozoites (*R*, *S*), which are set free into the body cavity of the insect host by the rupture of the wall of the oocyst. They collect as the result of an evident chemotactic influence in the salivary gland, and are injected into a new host when the insect bites. There they enter the erythrocytes and the life cycle begins anew.

The organisms included in this sub-order are the cause of serious diseases, and their number is being rapidly increased by the investigations of most recent times. Many doubtful forms have also been placed temporarily under this heading, so that it is impossible to give a synopsis of the genera, or to fix the precise limits of the sub-order itself.

Most prominent of the forms which are included here are the parasites of human malaria. Grassi still regards these all as merely varieties of one species. This is clearly doing violence to the ordinary zoological significance of the word. On the other hand, several investigators have grouped them into two genera, a plan which I myself followed in an earlier paper. Here they will be treated as three species of one genus in accord with a recently expressed view of Schaudinn, and with the known facts regarding their clinical manifestations, structural differences, and life histories.

The genus *Plasmodium* includes in addition to these species the parasite of avian malaria also. It was established in 1885 by Marchiafava and Celli, and although the name is employed here in a sense utterly at variance with its meaning as a term in general scientific use, yet the rules of zoological nomenclature call for its retention. The malarial organism was first seen and figured by Klencke in 1843 without any idea of the significance of the structures viewed. Laveran in 1880 was the first to attach etiologic significance to the structures he described from the erythrocytes in cases of malaria. A large number of investigators participated in the gradual elucidation of the schizogony of these parasites. It was 1896. however, before Manson set forth distinctly the agency of the mosquito in transmitting the disease. Just a year later Ross actually followed for the first time the fate of the parasites of avian malaria in the mosquito's stomach, and their development up to the infection of a new host by the sporozoites. Ross' observations on avian malaria were confirmed soon after by Grassi and other Italian investigators for human species of the malarial parasite.

The complicated terminology in this group, due to the continual changes introduced by various investigators, renders it advisable to give here for general information the table prepared with such success by Lühe, which shows the correspondence in the nomenclature of the chief investigators of recent date. The terminology of Schaudinn, which is followed in this article, has been more generally adopted than any other, and has much in favor of it from every standpoint. (See table below.)

The extensive consideration which the subject has received in previous articles in the REFERENCE HANDBOOK (compare *Malaria*, *Mosquito in Relation to Human Pathology*, *Plasmodium Malariæ*) renders it necessary here only to insert a brief diagnosis of the three species, and refer to the articles noted for further details.

Plasmodium malariæ (Laveran 1883).—(Syn.: *Oscillaria malariæ* Laverian 1883; *Plasmodium* var. *quartana* Golgi

Schaudinn, 1899 and Lühe, 1900.	Ross, 1898.	Ross, 1899 and 1900.	Ray Lankester, 1900.	Harvey Gibson, 1900.	Koch, 1899.	Grassi, 1898-1899.	Grassi, 1900.
Schizogony....	....	....	....	....	Endogenous development.	Sporulation (fase asporulare).	Monogonia (generazione neutrale) per sporogonia conitomica.
Schizont	Sporulating form.	Sporocyst (young form: amœbula s. myxopod)	Oudeterospore .	....	Full grown parasite.	Amœboid form	Mononte.
Merozoite	....	Spore; becomes later after entrance into erythrocyte amœbula (s. myxopod).	Nomospore	....	Theilungskörper.	1898: amœbula .... 1899: sporozoite.	Sporozoito (monogonico).
Macrogamete..	....	Macrogamete (female gametocyte); young form: amœbula s. myxopod).	Gynospore.. ...	Ovum....	Female parasite	Macrogamete s. ooid.	Makrospora }
Microgametocyte.	Flagellated body.	Male gametocyte (young form: amœbula s. myxopod).	....	....	Male parasite ..	1899: mikrogametogen.	Anteridio } gameti.
Microgamete ..	Flagellum..	Microgamete	Androspore	Sperm ...	Spermatozoon..	Mikrogamet s. spermoid.	Microspora }
Ookinete (copula sporont).	Vermicule ..	Zygote................	Gametospore ...	Oosperm .	Würmchen.....	1899: zygote	Vermicolo } amfionte.
Oocyst (copula sporont).	Coccidium..	Zygote................	Gametospore ..	Oosperm .	Coccidienartige Kugel.	1899: zygote	.... }
Sporoblast.....	....	1899: zygotomere...... 1900: mere, becomes blastophore.	....	....	....	....	Masse citoplasmatiche più o meno poligonale.
Sporozoite.....	Germinal rod.	1899: zygotoblast...... 1900: blast.	Gametoblast s. gametoclast s. filiform young	Zooid	Sichelkeim	1899: spore .... 1899: sporozoite....	Sporozoito (amfigonico). Young form: sporoblasto s. sporozoitoblasto.
Sporogony.....	....	....	....	....	Exogenous development.	Exogenous development.	Amfigonia (generazione sessuale) per sporogonia conitomica.

1890; *Hæmamœba malariæ* Grassi et Feletti 1892; *H. Laverani* var. *quartana* Labbé 1894; *Pl. malariæ quartanum* Labbe 1899.)

Young form in erythrocyte small, unpigmented; movement slow; pigment in coarse granules, first visible in about twenty-four hours, and peripheral in position. Movement decreasing until in sixty hours after the attack, or twelve hours before the next, the spherical *Plasmodia* fill almost the entire corpuscle. Having reached a diameter of about 0.007 mm. schizogony begins, and nine to twelve (rarely six or fourteen) merozoites are formed which are very regular (Fig. 5183, *e*). The melanin granules move in radial lines and collect in the central residual mass, from which the merozoites separate themselves in seventy-two hours. The synchronous release of these germs brings another paroxysm at this time, whence the name of quartan fever for the disease induced by this species, which is also often designated the quartan parasite. The gametes are few in number, spherical, and characterized by active streaming in the protoplasm. The sporogony of this species in *Anopheles* goes on at a minimum of 16.5° C., and stops before the maximum of 30° C. is reached. *Plasmodium malariæ* is found farther north than either of the other human malarial parasites, but does not extend into the tropics.

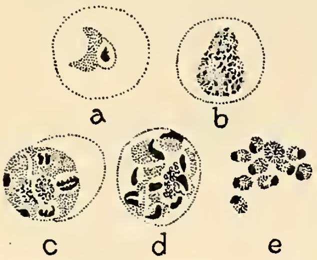

Fig. 5183. — *Plasmodium malariæ*, Schizogony. *a*, *b*, Growth of schizont; *c*, nuclear division; *d*, formation of merozoites; *e*, release of same by destruction of erythrocyte, residual mass at upper side of group. Magnified. (After Bastianelli and Bignami.)

Plasmodium vivax (Grassi et Feletti).—(Syn.: *Hæmamœba vivax* Gr. et Fel. 1892; *Pl.* var. *tertiana* Golgi 1889; *H. Laverani* var. *tertiana* Labbé 1894; *Pl. malariæ tertianum* Labbé 1899.)

Young stages in the erythrocytes are very active. Pigment granules are fine, and light brown in color. The fully grown schizont completely fills the red corpuscle, which is usually swollen and bleached in color. This stage measures 0.008–0.01 mm. in diameter, and produces fifteen to twenty merozoites in schizogony, which requires for its completion just forty-eight hours, whence the common names of tertian fever and tertian parasite. The pigment forms a solid mass in the centre, and the merozoites form a double ring about it, or more frequently an irregular mass. Schizogony occurs preeminently in the spleen. The gametes are abundant at a certain period, of spherical form, and distinguished from the schizonts above all in the form of the pigment, which is in coarse granules or bacilliform masses. They reach two to three times the diameter of an erythrocyte. The sporogony in the body of *Anopheles* requires eight days at a temperature of 28°–30° C.; 17° C. is the minimum for this stage of development. This corresponds to the occurrence of the disease in the tropics and subtropics. The relation of the body temperature of the host to the development of the parasite is well shown in the accompanying diagram (Fig. 5184).

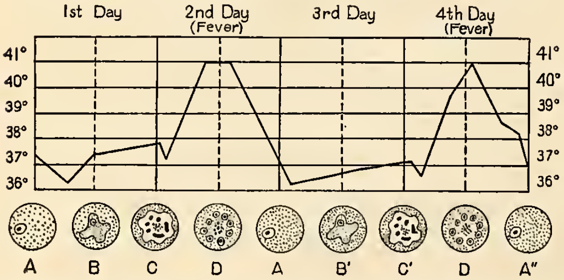

Fig. 5184.—Development of *Plasmodium vivax* in Relation to Temperature Curve of Patient. (After Doflein.)

Plasmodium immaculatum (Grassi et Feletti).—(Syn.: *Laverania malariæ* Gr. et Fel. 1890; *Hæmamœba malariæ præcox* Gr. et Fel. 1892, nec. *H. præcox* Gr. et Fel. 1890. *Hæmamœba immaculata* Gr. et Fel. 1892; *Plasmodium præcox* Doflein 1901.)

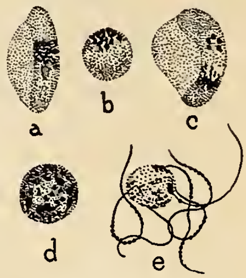

Fig. 5185.—*Plasmodium immaculatum*; Development in Stomach of *Anopheles claviger*. *a*, Macrogamete with remnant of erythrocyte; *b*, same one-half hour after ingestion by mosquito; *c*, microgametocyte with remnant of erythrocyte; *d*, same one-half hour after ingestion, the nucleus has divided several times; *e*, microgametes still attached to residual mass (so-called polymitus stage). Highly magnified. (From Braun, after Grassi.)

This is the smallest of all human malarial organisms. Fully grown schizonts measure only 0.005 mm. in diameter. Young form very active; pigment moderate in amount, very fine in peripheral zone. The schizont may also remain unpigmented, and this form has been regarded as a separate variety. Multiple infection of an erythrocyte is not rare, and the assumption of a signet-ring form is very common. The erythrocyte shrinks during the growth of the parasite. In schizogony seven, ten, or twelve merozoites are formed, rarely twelve to fifteen, and these are small, being only 0.001–0.0015 mm. in diameter. The length of the schizogonic cycle is not well determined, as the process takes place in internal organs, especially the spleen. It is apparently irregular, though forty-eight hours seems most probable. The gametes are crescentic or reniform, and originate especially in bone marrow. Further changes have been most carefully followed in this species. In the stomach of *Anopheles* these crescents become spherical (Fig. 5185) and the microgametes are formed and set free. The fertilization is completed by the fusion of a single microgamete with a macrogamete; and the resulting motile ookinet (Fig. 5186, *a*) penetrates the wall, entering first an epithelial cell and coming later to lie between the layers of the wall (Fig. 5186, *b*). The oocyst forms no special covering, but increases rapidly in size. Sporoblasts and then sporozoites are formed; the latter have a length of 0.014 mm. and a thickness of 0.001 mm., and are produced to the number of ten thousand in a single oocyst. After the rupture of the latter they accumulate in the salivary gland, lying in the secretion either within the cells or in the duct itself, whence they are expressed in the act of biting (Fig. 5187).

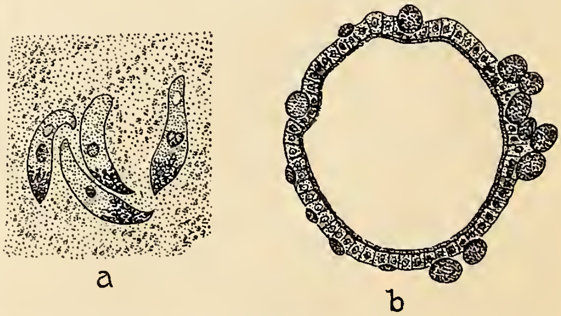

Fig. 5186.—*Plasmodium immaculatum*. *a*, Ookinet in stomach of *Anopheles claviger* thirty-two hours after ingestion; *b*, transsection of stomach with partly developed oocysts several days later. Magnified. (From Braun, after Grassi.)

The sporogony requires eight days at a temperature of 28°–30° C., and 18° C. is the minimum temperature for the infection of *Anopheles*. This species gives rise to the malarial fever designated as æstivo-autumnal, perniciosa, tropica, etc., and is epidemic only in the tropics and subtropics. This is the form which has been rated as a representative of another genus, *Laverania malariæ*, by many observers. While its separation from the genus *Plasmodium* is perhaps a convenience, it seems hardly justifiable on scientific grounds, as the differences between it and the other species are not of generic rank.

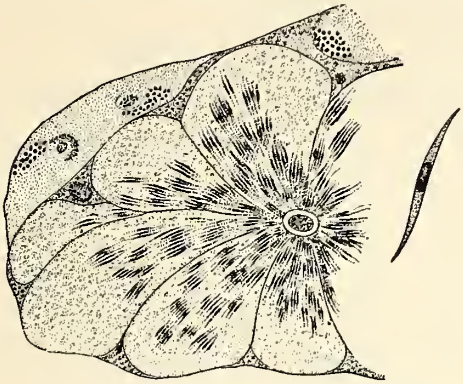

FIG. 5187.—Section Through Dorsal Sac of Salivary Gland from *Anopheles* with Groups of Sporozoites of *Plasmodium immaculatum* both in gland cells and in duct. Isolated sporozoite at right more highly magnified. (From Lang, after Grassi.)

Uncertain Species.—According to the work of certain investigators, particularly Celli, there exists a true quotidian malarial parasite, which is related to *Plasmodium immaculatum*, although smaller and completing the schizogony in twenty-four hours. The supposed species is found in Italy particularly in summer and fall, and is regarded by most authors as at most a variety of *Pl. immaculatum*. Still other forms from tropical regions have been regarded as distinct species without sufficient evidence as yet for this opinion.

There are yet other hæmatozoa of which it may be said that their exact relationship has not been sufficiently demonstrated to give them a definite place in the system, but which in all probability will be included in this suborder, though evidently not in the same genus with the malarial organisms just described.

In this connection should be noted the parasite of the spotted fever or tick fever of the Rocky Mountains, a new disease especially virulent in the valley of the Bitter Root River in Montana, where it has been known for twenty years, but present apparently also, though in milder form, in other parts of Montana, Idaho, Wyoming, Nevada, and Eastern Oregon.

Wilson and Chowning were the first to note ovoid intracapsular bodies in stained blood preparations, and to determine that in fresh blood these bodies manifest amœboid movements. These observations have been confirmed by later investigators, and the hæmatozoon is regarded by all as probably the cause of the disease. A brief description of the organism may be given here.

The smallest forms, or the first phase of Wilson and Chowning, are intracellular, ovoid bodies and measure 0.0015-0.002 mm. in length by 0.0005 to 0.001 mm. in thickness. They resemble slightly young schizonts of malaria, and more strongly the organism of Texas fever of cattle. These bodies occasionally change position in the corpuscle, and according to Anderson project pseudopodia quite rapidly. Two such bodies may lie in a single corpuscle. In the second phase the bodies are solitary in the erythrocytes, oval, ellipsoidal or spherical in form, and from 0.002 to 0.003 mm. thick by 0.003 to 0.005 mm. long. This phase is actively amœboid with the formation of pseudopodia in various directions. The third phase is seen in pyriform bodies arranged in pairs with the pointed ends approximated, and in rare cases distinctly united by a fine thread. This form is not amœboid.

Though the parasites are not found in large numbers in the circulating blood, only a few being present in each field of a preparation of freshly drawn blood, yet in the capillaries of tissues removed at autopsies from one to five per cent. of the erythrocytes are infected. This is marked in the lung, spleen, liver, and kidney, where also are found many red cells included in phagocytes, being faintly outlined within the protoplasm of the latter, and each containing a large parasite. In tissues taken some hours after death, the organisms are almost all spheroidal. They are present in the blood at least twenty-four days after recovery.

The organism is apparently transmitted by ticks, and all cases of the disease show a history of tick bites about one week before the onset. Stiles made a provisional determination of some ticks from the region as *Dermacentor reticulatus* but in correspondence later expressed the view that certain differences though slight justify placing these forms in a new species. Some facts point to the existence of another normal mammalian host for the parasite, and the gray gopher has been indicated as the most probable form. Further study is necessary to establish the character and development of this parasite, its exact systematic position, and its positive relation to the disease. Its superficial resemblance to *Piroplasma bigeminum*, the cause of Texas fever in cattle, has already been mentioned.

Myxococcidium Parker, Beyer, Pothier 1903.—Schizogony unknown; sporogony in *Stegomyia fasciata*. Only one species, thus far imperfectly known.

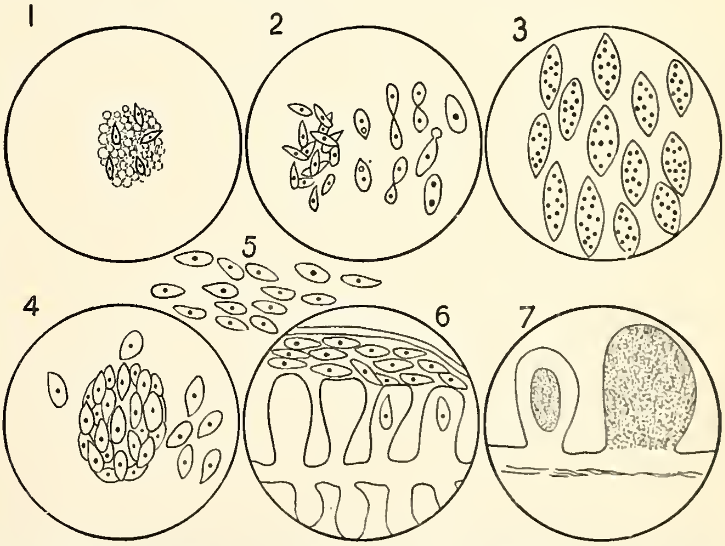

FIG. 5188.—*Myxococcidium stegomyiæ* from sections of mosquito killed (1) three days, (2) four days, (3) five days, (4) six days, (5) six to twelve days, (6) twelve days, (7) fourteen days after feeding on blood of yellow-fever patient. (Unpublished sketches, by courtesy of J. C. Smith.)

Myxococcidium stegomyiæ Parker, Beyer, Pothier 1903 (Fig. 5188).—A fusiform body (ookinet?) 0.003-0.004 mm. long by 0.0015-0.002 mm. broad in lumen of stomach and œsophageal diverticulum, about three days after mosquito has bitten yellow-fever patient; this body is provided with a nucleus. A spherical body (oocyst?) in the œsophageal diverticulum, embedded in an albuminoid mass of unknown character. This becomes mature and breaks up into numerous (thirty to forty) elongated oval bodies (sporoblasts?), 0.003 mm. long by 0.002 mm. broad, which enter the cells of the salivary gland, and then coming to rest (sporocysts), divide into numerous very minute bodies (sporozoites?).

The parasite was found in the yellow-fever mosquito (*Stegomyia fasciata*) from Vera Cruz, Mexico, by Drs. Parker, Beyer, and Pothier, Working Party No. 1, Yellow-Fever Institute of the United States, Public Health and Marine Hospital Service. According to these authors the mosquitoes used were fed on the blood of a yellow-fever patient, and with due precautions against infection from any other source were killed at stated intervals from the second to the thirtieth day. A careful study of sections of these mosquitoes in which the Working Party mentioned received valuable assistance from Mr. J. C. Smith, of New Orleans, resulted in the demonstration of the life history of the organism somewhat imperfectly as outlined above. More recently, however, Carroll has maintained that the fusiform stage is actually a wild yeast.

The Working Party also states that yellow fever was produced experimentally with mosquitoes from a case that harbored this parasite, and the parasite was found again in mosquitoes fed on this case. Furthermore they permitted this same species of mosquito to feed on a case of malarial fever of the malignant type, on normal blood, and on other nutritive materials, and in none of these mosquitoes were found the parasites described above.

From the account given it appears that there was present in these mosquitoes a parasite, the development of which bears close resemblance to that of the malarial organism in the sexual cycle (sporogony). On the analogy of the latter parasite there should also occur in this case a non-sexual cycle (schizogony) in the blood (?) of the yellow-fever patient. Yet Sternberg, Reed, Carroll, and many others have sought in vain for such an organism; nor was the Working Party more successful. The further life history of *Myxococcidium stegomyiæ* lies even beyond conjecture, and it can only be said that negative evidence raises a strong presumption in favor of its etiological relation to yellow fever.

Quite recently Councilman, Magrath, and Brinckerhoff have made known the results of studies on the organisms of vaccinia and of variola, which go far toward establishing the nature of these oft-reported and much-questioned bodies. Much is needed to confirm these reports and to elucidate further details in life history, as well as the general relationship of these bodies. They may be considered briefly here without prejudicing the results of further study on these points. Before vesicle formation in the diseases noted, small, structureless bodies (0.001–0.004 mm. in diameter) occur in vacuoles of cells in the lower layers of the dermal epithelium. With increase in size the body shows granules lying in a reticulum, and becomes irregular in form as if amœboid. No nucleus was demonstrated. Formation of small round bodies, 0.001 mm. in diameter, closes the first stage in the life cycle. Following this oval or ring-like intranuclear bodies appear. In them several vacuoles are seen grouped around a central vacuole. They enlarge and destroy the nucleus, and come to lie in a completely degenerated cell. The vacuoles become less evident, and there appear multiple circular bodies with a central dot. These bodies measure only 0.0015 mm. in diameter, and are seen with great difficulty.

The intranuclear bodies represent the second stage in the life history, which is believed to be the sexual cycle, and produce spores which are the infecting agents. In the opinion of these authors the first cycle may exist without the second, and such is the case in vaccinia.

Apparently these are the same structures seen by L. Pfeiffer, Guarnieri, and others, who were not successful in working out the life history as it now stands, although they also did not hesitate to bring them into etiological relation to smallpox. One of the most recent of these (Govini) has even described and figured both extranuclear and intranuclear bodies in vaccinia. Questionable intranuclear bodies have also been reported by several investigators for sarcoma cells in man, but there are also other parasites belonging to this group and affecting lower animals in which an intranuclear existence is well known, *e.g.*, *Eimeria salamandræ* (= *Caryophagus salamandræ*), parasitic in the intestinal epithelium of one of the salamanders, and most frequently in the nucleus of the cell parasitized.

Hæmatozoa have been described by various authors as characteristic of beri-beri or kakki, an endemic form of polyneuritis particularly prevalent in Japan and the Dutch East Indies. The infectious nature of this disease seems to be generally accepted, and at different times various forms of possible pathogenic significance have been reported from the blood. The most recent of these are amœboid bodies resembling malarial parasites, which have been studied and described at length by Glogner, and especially Fajardo. The latter demonstrates their presence in the blood in peripheral as well as inner organs, and their production of pigment and formation of spores of some sort; and yet the possible confusion with malarial or other hæmatozoa and the lack of proof concerning the distinct etiological relation to beri-beri have prevented any general acceptance of the rôle assigned to the organism.

In leukæmia also Löwit claims to have discovered amœboid organisms in the leucocytes, and to have followed their development even to sporulation, *i.e.*, schizogony. (For further details see *Leukæmia*.) The parasitic nature of such structures cannot be regarded as established until they have been studied in life and not merely in preparations of fixed blood.

In dengue, an infectious disease epidemic in hot climates, and treated at length in an earlier volume (*q.v.*) good evidence has recently been furnished that the cause is a protozoön analogous to the malarial organism, and like it transmitted by the mosquito. It is an unpigmented pyriform body found in the erythrocytes though not abundantly, and is present in second and third attacks as well as in the first. The development is slow, requiring four to eight or even ten days, and in general appearance the organism suggests *Piroplasma bigeminum* of Texas fever in cattle or the organism of spotted or tick fever in man noted above. The discoverer, Graham, also found spores in the walls of the stomach and salivary glands of the mosquito, though this portion of the life history has not yet been clearly described; in one case the time required for it was, however, only forty-eight hours. In this case it is *Culex fatigans* which harbors the organism and transmits it, although other species may also be responsible. Graham has recently reported inoculation experiments, the results of which leave little doubt as to the cause of the disease and the method of transmission.

A long series of contributions concerns objects of supposed protozoan character which have been brought into etiologic connection with various pathological conditions by investigators of the most diverse type. Such are the pseudococcidia of epitheliomata, of sarcomata, of molluscum contagiosum, etc. Three views obtain as to the nature of these bodies, according to which they are blastomycetes or myxomycetes, sporozoa or other protozoa, and finally degenerative cell products. It cannot be said that their animal nature has been at all clearly demonstrated, and beyond the mere mention they have no right to consideration in this article.

In the subclass Neosporidia are included forms which in the adult condition are multinuclear, and which produce spores during the entire vegetative period. Spore formation is very characteristic. The organism forms a number of pansporoblasts, which divide again to form sporoblasts. The latter acquire a membrane and transform themselves with somewhat complicated changes into sporocysts, each of which develops within itself only a single sporozoite. Of the two orders only the

Sarcosporidia are of importance here, and they are but imperfectly known.

The Sarcosporidia possess an oval, elongate, or sacculate body (Fig. 5189), in which pansporoblasts are formed at a very early period. They parasitize at first intracellularly the muscle fibres, but by the degeneration of these come to lie in connective tissue and develop to oval or spherical bodies of considerable size. In the youngest stages yet found uninuclear spheres 0.004–0.005 mm. in diameter with relatively large nuclei (0.002–0.003 mm.) occur in the endoplasm. The protoplasm forms a frame-work between these young pansporoblasts, which increase in size with age and become also multinuclear. While at the ends of the sacculate body new pansporoblasts are continually being formed, in the older ones nearer the centre the contents divide into many finely granular pale spheres, the sporoblasts.

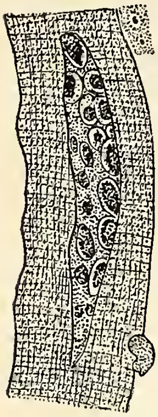

FIG. 5189.—*Sarcocystis tenella*. Longitudinal section of young stage with newly formed uninuclear pansporoblasts. Magnified. (From Wasielewski, after Bertram.)

In each of the latter is formed a single sporozoite which gradually assumes the definitive form (Fig. 5190, *a–d*). These sporozoites are usually reniform, sickle-shaped, or crescentic and very small. Some investigators claim to have discovered a polar capsule, and this has been partly confirmed by some later observers. Polar filaments are present in some cases (Fig. 5191, *b*). Theobald Smith has observed the movements of the sporozoites, and finds that in *Sarcocystis muris* there is a peculiar gliding with sudden revolutions on the long axis. This is carried out without the assistance of flagella. Smith's experiments, which were very painstaking and extended over three years, demonstrate for this species direct infection by feeding muscle tissue in which was present the parasite with ripe, mobile sporozoites. Sarcosporidia are parasitic in vertebrata, chiefly mammalia, and are common in many domestic animals.

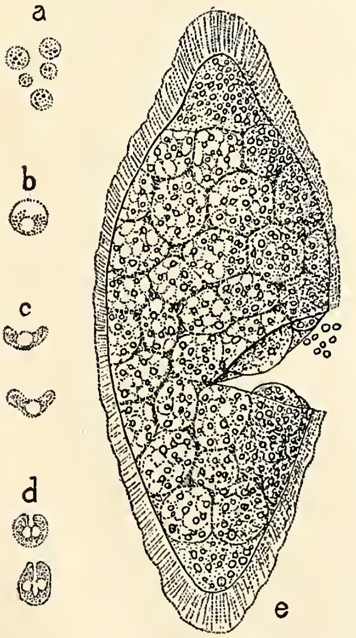

FIG. 5190.—*Sarcocystis miescheriana*. *a–d*, Development of sporozoites from sporoblasts; *e*, full-grown sac, dissected out from muscle fibre, the radially striated capsule torn on the right to show the pansporoblasts within. Magnified. (From Wasielewski, after Manz.)

Miescher in 1843 found these parasites first as cylindrical sacs in the voluntary muscles of the house mouse. Some years later Rainey found similar structures in the muscles of the pig, and the common names of these structures, often visible to the naked eye, are associated with these two investigators. The group has been but little studied, and the system is so imperfectly developed that it is advisable to omit all further mention of it, and to pass at once to a consideration of the one species which has been certainly obtained from the human body,

Sarcocystis Lindemanni (Rivolta 1878).—(Syn.: *Gregarina Lindemanni* Rivolta 1878; *Sarcocystis hominis* Rosenberg 1892; *S. Lindemanni* Labbé 1899.)

Protoplasmic body from the muscle fibres of the vocal cords, from 0.15 to 1.6 mm. long and from 0.077 to 0.17 mm. thick; membrane delicate, somewhat thickened at the ends (Fig. 5191, *a*), body distinctly chambered (Fig. 5191, *e*). Sporozoites (*d*) banana shaped, exceedingly numerous, 0.008–0.009 mm. in length.

The most certain case is that of Baraban and St. Remy, who found this form in the body of a criminal executed at Nancy. All the specimens of the parasite were in the same stage of development. The infected muscle fibres were swollen to fourfold their normal thickness. Several other uncertain cases are on record. As Theobald Smith remarks, the muscular system is not subject to the scrutiny which the viscera undergo in pathological investigations, so that the presence of these forms may be much more frequent and important than appears as yet. In the case of *S. muris* Smith has shown that the feeding of muscle tissue containing ripe mobile sporozoites to gray and white mice is followed by an invasion of the muscle fibres by the parasites, which readily become recognizable after the forty-fifth day. Nothing is known regarding the development of *S. Lindemanni*.

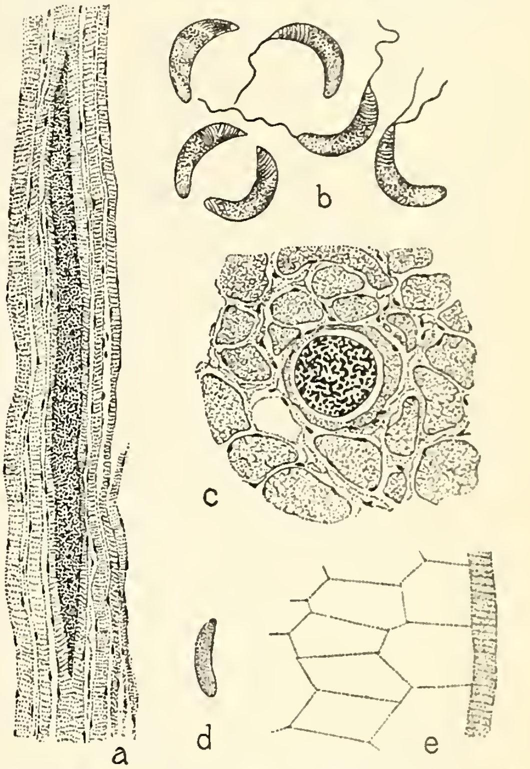

FIG. 5191.—*Sarcocystis Lindemanni* from Human Larynx (except *b*). *a*, Longitudinal section of muscle fibre with fully developed sac. × 250. *c*, Transverse section of same. × 250. *e*, Section showing chambers emptied of pansporoblasts. × 565. *d*, Sporozoite. × 1,350. *b*, Sporozoites of *S. Blanchardi* with polar filaments. × 875. (*b*, From Wasielewski, after van Ecke; other figures from Doflein, after Barbaran and St. Remy.)

The class Infusoria holds the highest rank among Protozoa, and its members are at once distinguished by the presence of peculiar organs of locomotion in the form of fine hair-like protoplasmic processes, the cilia, which are present in at least some part of the life history of all individuals in the group. By virtue of the greatly inferior length, the much larger number present on each animal, and the simple synchronous movement cilia are easily distinguished from flagella. The external zone or ectoplasm is more highly differentiated than in the forms of

Protozoa thus far considered, and the body has in consequence a more permanent form, which tends to acquire in all free species a bilaterally symmetrical structure. In the ectoplasm one finds special contractile fibrils, or myophanes, and peculiar unexplained bodies known as trichocysts. The cilia are arranged in rows, and occasionally fuse into vibrating membranes or stylet-shaped masses, cirri, in furtherance of the motor function. The firm ectoplasm forms at the mouth opening (cytostome) a groove (peristome), or a peculiar funnel-shaped pit (cytopharynx), which serves to admit food particles to the interior of the body. A differentiated anal orifice (cytopyge) is only rarely found. The contractile vacuole is always present, and often two or more occur with a more or less extended canal system branching in all directions.

One of the most striking peculiarities is found in the nuclear conditions. Typically two nuclei are present; a large somatic nucleus or macronucleus, and a small sexual nucleus or micronucleus, which usually lies close to the former. The macronucleus is always single, but there may be several micronuclei to each cell. The ordinary process of reproduction is fission or gemmation, and in this the macronucleus divides amitotically while the micronucleus undergoes indirect or mitotic division. At times one finds conjugation, or temporary and partial fusion of two individuals with the destruction of the macronuclei and of a certain portion of each micronucleus, while the remainder of each micronucleus on each side is divided equally between the two individuals. From the portions of the micronuclei fused there arise new macronuclei and micronuclei. This process has generally been looked upon as one of rejuvenation, and necessary for the continued existence and reproductive power of the individual. Certain recent investigations leave this somewhat uncertain. The complicated details of the process find, however, an evident parallel in changes connected with the fertilization of higher forms, or the union of egg and sperm cells.

Encystment is frequent, and the evident means of providing for unfavorable changes in environment, such as drought, temperature changes, etc. In parasitic forms it is related to the necessary interval of transport to a new host. In the majority of cases these protozoa are commensals rather than true parasites, and in some instances are even said to be of mutual advantage to the host, and consequently symbiotic in character. The two subclasses are distinguished on the basis of the permanence of the ciliary covering which is constantly present in the Ciliata, save during encystment, but which is found only in the young forms of the Suctoria. The latter are also supplied with peculiar sucking tubes for taking in nourishment. They do not furnish any forms found in the human body.

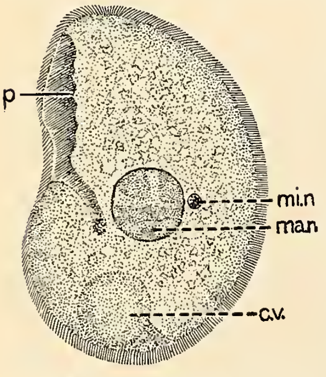

FIG. 5192.—*Nyctotherus faba*, Living. *c.v.*, Contractile vacuole: *ma.n.*, macronucleus; *mi.n.*, micronucleus: *p*, peristome. Magnified. (After Schaudinn.)

The Ciliata are present in large numbers in all fresh-water bodies, and manifest great variety of structure. They furnish many ectoparasitic species on water-living vertebrates and a few endoparasitic in higher forms, including man. The various orders into which the Ciliata are divided are based upon the number and arrangement of the cilia in the adult form. Only two of these orders call for attention here. In the Holotricha there is no spiral zone of prominent cilia or membranellæ leading to the cytostome, and the body possesses only small cilia which are more or less generally distributed. The Heterotricha have an adoral spiral zone of larger cilia, but the remainder of the body is uniformly finely ciliated.

Of the Holotricha one species has been reported from man. It belongs to the genus *Chilodon*, the distinctive features of which are included in the description of the species which follows.

Chilodon dentatus (Dujardin 1841).—(Syn.: *Loxodes dentatus* Duj. 1841; *Ch. dentatus* Guiart 1903.)

Oval, 35–55 μ long by 25–35 μ broad, flattened in ventral face, dorsal aspect strongly arched. Anteriorly a flexible membranaceous projection curved toward the left and carrying several rows of cilia on the lower aspect. Granular endoplasm confined to posterior inflated region; ectoplasm in a thin peripheral layer and forming the anterior projection. Mouth ventral, in anterior portion of the endoplasmic region, normally contracted and hardly visible, cytopharynx directed dorsally and recurved ventrad so as to form almost a complete circle. Two contractile vacuoles, macronucleus large, spherical, in posterior region.

This infusorian has been found once by Guiart, as a parasite of the human intestine in Paris, France. The animals were present in large numbers in the mucus from dysenteric stools. Care was taken to control the source of the parasite and to avoid contamination from external sources, with the result of obtaining from the dejecta on the second day after passage pure cultures of the infusorian. It is a common free-living species, and must be classed in this instance merely as an accidental parasite. Close examination of fæcal discharges will undoubtedly show the occasional occurrence of many such, especially when the resting spores happen to be abundant in the local supply of drinking-water. In this case there is nothing to show that the resting spores did not simply make the passage of the canal, and then develop almost at once in the discharges. The extreme sensitiveness of the species to changes in the environment, which has been commented upon by Guiart himself, makes this explanation of the case more probable. One should recall in this connection the record of Schaudinn, that the resting spores of a Rhizopod, *Chlamydophrys stercorea*, must make the passage of the alimentary canal in man or other animals in order to undergo development. In this case, indeed, the resting spores open in the colon and an amœboid organism emerges which does not assume the testaceous form of the adult until after the fæces are discharged from the body.

The order of the Heterotricha, already generally characterized, includes three species under two genera, which have been reported from the human host. The first belongs to the genus *Nyctotherus* Leidy 1849, which contains flattened reniform species with a peristome along the concave side from the anterior pole to the cytostome at the centre. The cytopharynx is more or less arcuate. The macronucleus is large and nearly central in location. A single contractile vacuole is present. The species of this genus occur as parasites in the alimentary canal of Anura, Myriapoda, and Insecta. A single form has been found twice in the human alimentary canal.

Nyctotherus faba Schaudinn 1899.—Body reniform, somewhat flattened dorsoventrally, left side convex, right concave and notched in the centre. Anterior end bent to the right a little, and on the right side slightly cut out; posterior end broadly rounded (Fig. 5192). Length 0.026–0.028 mm., breadth 0.016–0.018 mm., thickness 0.01–0.012 mm. Peristome a narrow longitudinal slit just at right margin of body, extending from near anterior end to middle of body. Cytopharynx tubular, short, and without guide spine at entrance. Cilia very fine and delicate as well as short. Ectoplasm thin, endoplasm granular, alveolar and without food vacuoles. Contractile vacuole large, located left of middle, near posterior end, emptying through the special anal tube. Macronucleus spherical, 0.006–0.007 mm. in diameter, with chromatin in four or five solid masses near periphery, leaving the intervals filled by a non-staining linin network. Micronucleus 0.001–0.0015 mm. in diameter, spherical or oval, ordinarily next the macronucleus. Fission and conjugation were not observed. Encysted form oval, easily recognized by the strange macronucleus.

This species has been found only once in Berlin in a patient suffering alternately from diarrhœa and constipation. It occurred in large numbers in the fæces taken direct from the intestine, and was accompanied by *Balantidium minutum* and eggs of *Anguillula* (?) and *Anchylostoma*. The species has an especial interest here since the German physicians suggest from the history of the case that the infection may well have been attained in the United States, where the patient had lived for some time previously. A pathogenic rôle has not been attributed to the species.

Stiles reports in recent correspondence that he has encountered several cases of ciliate infection which could not be identified and at the time more exact study was impracticable. The attention of physicians should be directed more carefully to this group of organisms.

The genus *Balantidium* includes species of oval or ellipsoidal form, circular in transsection, with the anterior end somewhat tapering. The peristome has the form of a flattened funnel with the cytostome at its base. Two contractile vacuoles on the right side, sometimes two others on the left. Cytopyge terminal; macronucleus oval or reniform. The five known species are parasitic in the alimentary canal of man (two species), pig (one species), and amphibia, and in the body cavity of polychætous annelids. For the distinction of the human parasites a key to all five species is necessary. That given here is taken from Schaudinn.

1. Peristome extends to equator of body or further, cytopharynx present.......................................2
Peristome much shorter, cytopharynx wanting.....3
2. Four contractile vacuoles, macronucleus reniform, cyst spherical........*B. entozoon* Clap. and Lachm.
One contractile vacuole, macronucleus spherical, cyst oval......................*B. minutum* Schaudinn
3. Two contractile vacuoles.............................4
One contractile vacuole macronucleus oval, cyst spherical................................*B. duodeni* Stein
4. Body elongated, spindle-shaped, or cylindrical, *B. elongatum* Stein
Body oval.............................*B. coli* Stein

Balantidium coli (Malmsten 1857).—(Syn.: *Paramæcium coli* Malmsten 1857; *B. coli* Stein 1867.)

Form oval, slightly truncated anteriorly with very short infundibuliform peristome which lies just to the right of the anterior tip and leads to a short cytopharynx (Fig. 5193). Body 0.07–0.1 mm. long by 0.05–0.07 mm. broad. Ectoplasm and endoplasm distinct; latter with drops of oil and mucus, and according to some observers red and white corpuscles from the host. Macronucleus bean-shaped or reniform, with the small spherical micronucleus adjacent to it. Two contractile vacuoles located on the right side, but no permanent cytopyge. Fission of the free form has been observed. Conjugation has also been seen. Cysts are spherical and possessed of impervious membrane.

This species inhabits the colon of man and the pig. In the latter it occurs also in the rectum and cæcum, and is present regularly in large numbers. The pig may be regarded as the normal host, and in it this species excites no abnormal symptoms. The encysted forms evacuated with fæces are supposed to bring about the transfer of the species all the more easily that the pig is coprophagous; and yet experimental infection has been unsuccessful even in the pig. Grassi and Calandruccio have demonstrated that experimental infection of man is not successful in the case of healthy individuals. The occasional introduction of encysted forms may, however, bring about successful colonization of the canal whenever any pathologic conditions exist in the colon, although Grassi and Calandruccio argue from the slight difference in size and the failure of their experiments that the forms found in man are not of the same species as those from the pig. These conclusions do not seem to have found even limited acceptance.

Malmsten discovered *Balantidium coli* in 1857 in a man who had recovered from an attack of cholera two years before, but had since suffered from diarrhœa. The parasites were abundant in the bloody discharge of a rectal abscess, and even after its disappearance persisted in the fæces, from which they finally disappeared as a result of the use of acid enemata. In the necropsy of a subsequent case the exact seat of the parasite was determined as the anterior region of the large intestine.

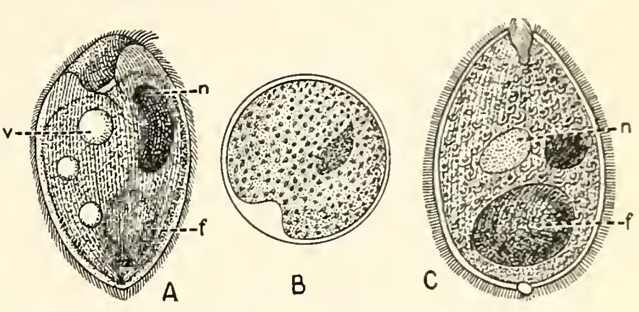

Fig. 5193.—*Balantidium coli*. *A*, *C*, Free; *B*, encysted; *n*, macronucleus; *v*, contractile vacuole; *f*, food mass. Magnified. (*A*, After Leuckart; *B*, *C*, from Braun, after Casagrandi and Barbagallo.)

Many cases have been reported from man since then. Shegalow lists sixty-three in all from Russia, Germany, Scandinavia, Finland, Italy, Cochin China, Sunda Islands, and the United States of America. Strong and Musgrave have added the Philippines to this list. While this parasite has been observed regularly in obstinate diarrhœa, its disappearance is not accompanied with the cessation of the symptoms in all cases, and Balantidia have been found after the diarrhœa has stopped. The earlier idea that these protozoa were the exciting cause of the intestinal disturbances has accordingly given way in part to a view that these protozoa continue and extend the diseased condition, but are not sufficient to cause it. Some authors report, however, that the species penetrates the intestinal wall and causes abscesses in the deeper layers. Solowjev claimed even to have demonstrated them in the blood and lymph vessels of the intestinal wall. This has recently been confirmed by Strong and Musgrave.

These authors, together with several other very recent contributors to this subject, contend very strongly in favor of the pathologic rôle played by the parasite. In most post-mortems lesions have been found similar to those of amœbic dysentery. Brooks found in apes in New York extensive ulcerations in the cæcum, irregular in contour with undermined borders. The mucous and submucous coats were destroyed and the parasites were present in great numbers in the ulcerations, especially on the floor and along the sides. They even pass beyond the limits of the ulcers, apparently following the course of the lymphatic and blood-vessels. It was surmised that the parasites entered the submucosa from the crypts of Lieberkühn, in the depths of which they were often found. The Balantidia were found in the diarrhœtic stools, but disappeared with recovery of the host. But relapses were frequent, and each time the parasites reappeared in the fæces. This is explicable on the basis of their position deep in the glands of the intestinal wall, and emphasizes the difficulty of completely destroying them and preventing a recurrence of the disease.

It is difficult to avoid the conclusion that positive proof of the etiologic significance of these forms is given by the presence of abundant parasites in the lesions and in the tissues in advance of the pathologic changes, and also by their occurrence in the depths of glands and in the submucosa before the start of such lesions at these points. The opponents of this view regard the rôle of the protozoa as secondary, and look upon bacteria as primarily responsible for the lesions. This species is known to occur abundantly in some parts of this country as a parasite of the pig, and its more frequent presence in the human host than records hitherto made would show may easily be disclosed by more careful examination. It should be noted that many of the cases already on record come from the country where the chances of accidental infection are naturally greater. It is there accordingly that one should look for evidence of more extended infection of the human host. Lack of records in the past may well be due to lack of precise examination among the very cases in which the parasite is most likely to occur.

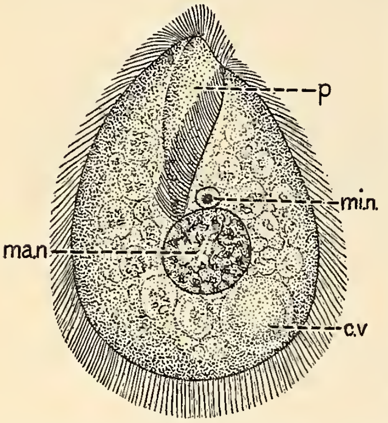

FIG. 5194.—*Balantidium minutum*, Living. Abbreviations as before. Magnified. (After Schaudinn.)

Balantidium minutum Schaudinn 1899.—(Syn.: *Colopoda cucullus* Schulz 1899.)

Body compressed pyriform or oval (Fig. 5194). Length 0.02–0.032 mm.; breadth 0.014–0.02 mm., or in the ratio 3:2. Anterior end bluntly pointed, often slightly twisted dextrad or sinistrad. Posterior end broadly rounded. Peristome a slender cleft, broader anteriorly, pointed posteriorly and deeper; extending from near anterior tip to centre of body; in the living animal continually opening and closing; left margin with hyaline membrane. Adoral cilia heavier and longer than those of the body generally, only on the left peristome margin beneath the membrane. Body cilia long (0.007–0.008 mm.) slender. Hyaline ectoplasm thin, distinct from granular endoplasm, which contains many vacuoles. These are filled with fine granules, and large food masses or excretory crystals are not present. Contractile vacuole single, near posterior end on left side. No permanent cytopyge. Macronucleus spherical 0.006–0.007 mm. in diameter; centrally located. Micronucleus single, anterior to macronucleus at its surface, 0.001 mm. in diameter. Division occurs, but conjugation has not been observed. Cyst oval.

Reported twice, once in company with *Nyctotherus faba* (*q. v.*) and once in Berlin also without that species. In both cases this form was abundant during the diarrhœa, but with the exception of a few cysts, disappeared as soon as the stools became firmer. Purgatives brought the infusorians again in numbers into the stools. This condition indicates that they inhabit the small intestine, perhaps the duodenum, rather than the colon, and make their appearance when carried outward by more fluid contents and rapid passage of the canal. As other species of the genus are harmless commensals in the canal of Amphibia, this species is probably not pathogenic. It should be kept in mind that confusion of *B. coli* and *B. minutum* may occur if the examination is not made with precision, and perhaps some cases of the former, already on record, actually concern the latter species.

As pseudo-infusoria may be designated a long series of structures reported from various sources, and often the object of repeated discovery by those unfamiliar with the field. Thus in mucus or sputum in case of affection of the air passages, bodies moved by cilia have been interpreted as genuine parasites and assigned an etiological rôle in the disease. In contravention of this view may be urged the variable and irregular form of such bodies, their rapid and special degeneration and their source, which amply demonstrate their origin as detached ciliated cells from bronchi, trachea, or nasal cavity. Such bodies are the asthma parasites of Salisbury, and the protozoa of whooping-cough described by Deichler and Kurloff.

Much less worthy of serious attention are the reports of various writers, especially Lindner, that certain forms, well known as free-living species, namely, unstalked vorticellids, are the cause of various gastric disturbances in man and certain domestic animals. The statement of Schaudinn, that he has found repeatedly active vorticellids in fresh fæces, but only after water enemata, is sufficient indication of the means by which such marvellous discoveries as those of Lindner and others are achieved. Quite recently I was asked to examine a slide containing organisms from fresh urine, and these were not echinococcus bladders as diagnosed, but unmistakably free living forms, and probably contracted rotifers whose presence was due to the contamination of the vessel, or possibly of the sample of urine examined.

Henry B. Ward.

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ADDENDUM.

"PROTOZOA IN SCARLET FEVER?*—In four cases of scarlet fever, which came to autopsy at the Boston City Hospital, there was found a series of bodies which strongly suggest the different stages in the development of a protozoon. These bodies occur in the epithelial cells of the skin and tongue, between these cells, and free in the superficial lymph vessels and spaces of the corium (see Plate LXII.). For description they may be divided into two groups.

"The first group consists of a series of bodies varying in size from 2 to 7 μ. Structurally they are composed of a finely granular, closely meshed reticulum. Sometimes they contain small vacuoles. Their frequently irregular and elongated forms suggest fixation while in amœboid motion.

"The bodies of the second group are radiated in structure and measure 4–6 μ in diameter. They contain a central body from which radiate a comparatively large number of narrow segments. All stages occur between radiate bodies or rosettes just forming, and others where the segments are enlarging and leaving the central body to form the small granular forms already described.

"These bodies are brought out best by staining in eosin followed by alkaline methylene blue after fixation in Zenker's fluid. They stain a clear blue in fairly well-marked contrast to the purplish nuclei and the pale pink protoplasm of the cells. Other staining methods give no differentiation of the bodies.

"The evidence that these bodies represent different stages in the growth of a protozoon is based on morphological data only, and necessarily is far from conclusive.

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* This communication and the accompanying photograph were not received until the main article had already been set up in type. —EDITOR.

EXPLANATION OF PLATE LXII.

Figs. 1 and 2 show numerous large and small scarlet-fever bodies in and between the epithelial cells of the rete mucosum. In Fig. 1 is a large body in a lymph space of the corium just underneath the epidermis. Several of the bodies suggest fixation while in amoeboid motion.

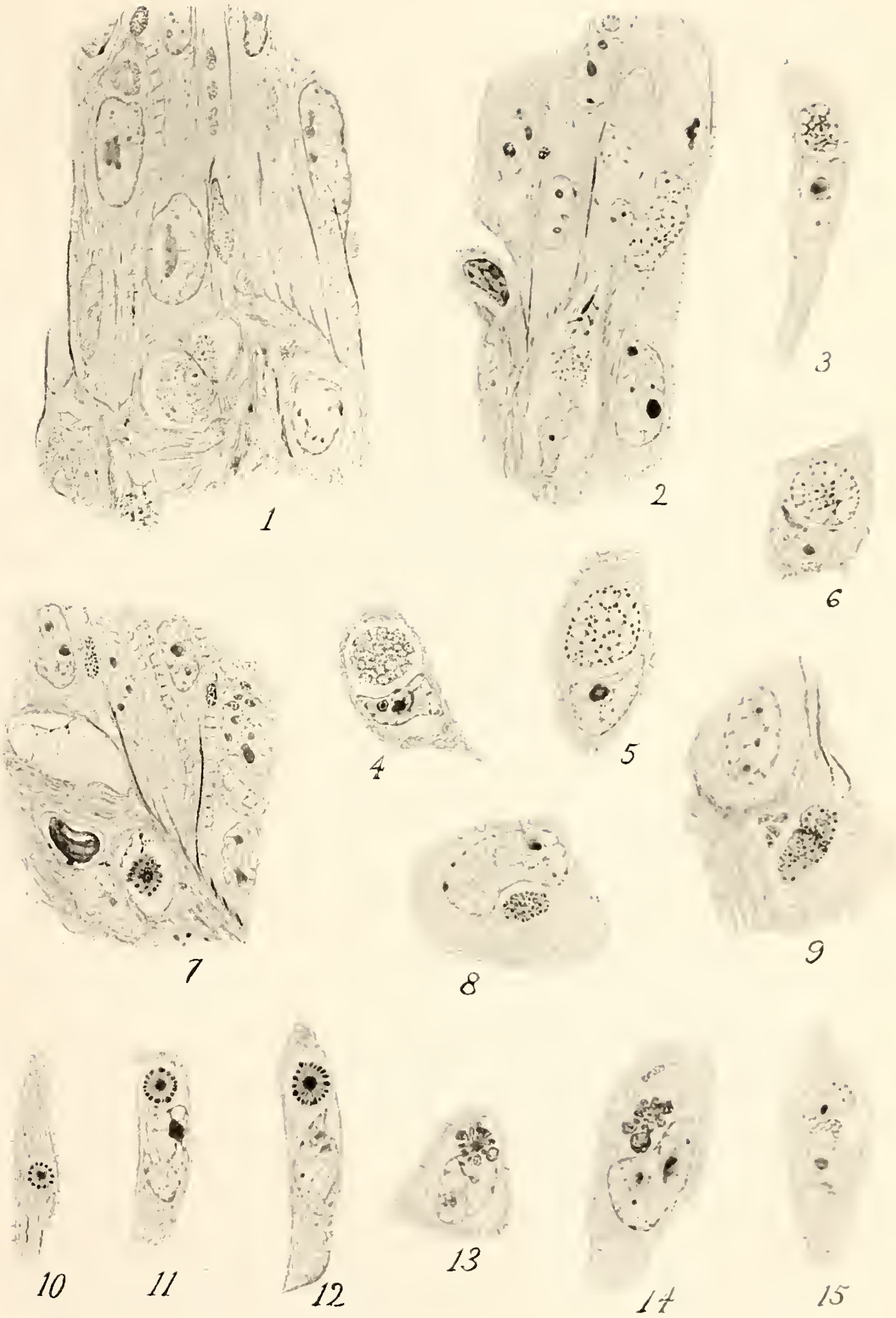
Figs. 3, 5, and 6 are coarsely reticulated forms which may be degenerated forms of the scarlet-fever bodies, or stages in sporogony.

Figs. 4, 8, and 9 probably represent stages preceding the radiate bodies. In Fig. 9 the bodies lie in a lymph space. It shows also four small forms which apparently have just freed themselves from a rosette.

Figs. 7, 10, 11, 12, 13, 14, and 15 show different stages in the development of the radiate bodies.

Fig. 10 is the earliest stage; there is a distinct central body and a definite regular arrangement of granules at the periphery. Figs. 7, 11, and 12 show a little later stage of development; 11 and 12 are optical sections, while 7 is a surface view. Moreover, in Fig. 7 the body lies free in a lymph space in the corium. The segments begin to show a certain amount of lateral separation from each other.

Fig. 13 is a still later stage; the segments are increasing in size and are more or less free from each other, although most of them are still attached to the central body. In Fig. 14 the segments are all free and enlarging, although still grouped around the central body. In Fig. 15 three bodies are still grouped around the central body, which is free.



PROTOZOON - LIKE BODIES FOUND IN FOUR CASES OF SCARLET FEVER
(AFTER F. B MALLORY)
Copied in monochrome tint from the colored drawings in the original paper
Journal of Medical Research, No. 4, Vol. X, 1904.

Their discovery may, however, prove to be the first step in clearing up the etiology of scarlet fever.

"Morphologically the bodies resemble fairly closely the different stages in the sexual development (schizogony) of the malarial organisms. Comparing them with the tertian malarial parasite under the same conditions of fixation and staining, they seem to be about one-third larger, and to have about twice as many segments in the rosettes.

"The accompanying illustrations (Plate LXII.) are a copy in black and white of the plate of colored drawings in the original paper." *

While these bodies must be studied in the living condition to demonstrate beyond question their protozoan nature, and while still further evidence must be adduced before their etiological relation to scarlet fever can be regarded as demonstrated, yet Dr. Mallory's work is of great importance and a strong presumption in favor of the view which he advocates. For his courtesy in furnishing these results in advance of the appearance of the article itself sincere thanks are due. *H. B. W.*

RADIUM.—Radium is a radioactive substance supposed to be a new element. Professors Curie and Demarcay have isolated in small quantity and tested what they consider to be pure radium, obtaining from their samples a characteristic spectrum, and have determined the atomic weight to be 225. On account of the rarity and great difficulty and cost of isolating radium it is used in the form of a bromide or chloride.

Discovery.—The discovery of radium is due to investigations upon radioactive substances. In 1896 M. Henri Becquerel, member of the Institute of France, reported the discovery that uranium gave off radiant energy having many of the properties exhibited by the radiations from x-ray tubes.

The radiations from uranium were given the name of Becquerel rays, from the distinguished scientist who discovered them. These rays have the property of discharging electrified bodies and of producing chemical changes in the silver salts ordinarily used in photography, in these respects being similar to the x-rays.

Uranium was first discovered in 1789 by the German chemist Klaproth, and named by him from the planet "Uranus." Uranium, though widely distributed, is never found in large amounts, and forms several minerals. The most common of these is uraninite, commonly known as pitchblende. It contains about eighty per cent. of uranium. The pitchblende which contains the largest amount of radioactive substances is the Bohemian pitchblende; but it is also found in Saxony, Cornwall (England), and in Colorado (United States).

Professor Curie and Mme. Curie, in investigating the Becquerel radiations from uranium found that some samples of pitchblende, from which the uranium had been extracted, gave forth radiations much more powerful than any they had found, having, in fact, four times the radioactivity of metallic uranium. They concluded that uranium being absent, the radiations were due to some unknown substance in the pitchblende, and following out this they discovered, in 1898, a substance to which they gave the name of "polonium." Polonium passes more rays through aluminum than uranium does, but these rays do not penetrate glass, are readily absorbed by minerals, and are cut off by thin paper. In the same year, following up the discovery of polonium, M. and Mme. Curie and M. Bemont isolated a second substance from pitchblende which possesses many of the chemical characteristics of uranium, but is much more powerful. To this they gave the name "radium."

Properties of Radium.—Radium is one of the most peculiar substances known to science, and produces phenomena which were hitherto unknown as existing in any chemical element or chemical combination: (*a*) It glows constantly with a visible light; (*b*) it gives off constantly a certain degree of heat; (*c*) it produces electrical effects similar to those produced by the x-rays; (*d*) it causes certain chemicals to fluoresce; (*e*) it reduces the silver salts ordinarily used in photography; (*f*) it transforms white into red phosphorus, and produces other transformations, such as changing the color of glass, porcelain, white paper, rock salt, etc.; (*g*) it has a distinct effect upon living tissue.

Nature of Radium Radiations.—The discovery of x-ray radiations and radium radiations has given rise to many ingenious theories, but experiments appear to show a distinct difference between radium rays and x-rays and the emanations from radium. Radium rays like x-rays pass through glass and substances opaque to ordinary light, while radium emanations are of peculiar character and appear to be more like a vapor. These emanations do not pass through glass, but settle upon all objects with which they come in contact, and like vapor of water may be condensed by extreme cold. The emanations from radium produce radioactivity in other substances, the result being, so far as is known, that all substances may be rendered radioactive through the influence of radium emanations. Substances so rendered radioactive present to a degree all the phenomena which radium itself presents, and when so charged retain the properties of radium for varying periods of time. The Curies have determined that substances thus rendered radioactive retain their induced radioactivity very much longer when guarded in a small enclosure through which the emanations cannot pass. In such cases the induced radioactivity diminishes one-half every four days, while in substances not so guarded it diminishes one-half every twenty-eight minutes.

Nature and Measurements of Radium Radiations.—There are three entirely distinct types of rays emanating from radium. These are known as the "α," "β," and "γ" rays. The α rays are the least penetrating, losing about one-half of their intensity if passed through aluminum 0.0005 cm. in thickness. The β rays are much more penetrating and much longer, and correspond in every particular to the characteristics of cathode rays. They are readily deflected by a magnet, discharge electrified bodies, etc.

The γ rays are the rays possessing the greatest penetrating power. These rays will produce radioactivity through the air at a distance of four feet or more, and are so much more penetrative than α rays that they require aluminum 8 cm. in thickness to reduce their intensity one-half.

The radioactivity of radium compounds is measured in terms of uranium, this element being taken as a standard. Professor Curie states that pure radium possesses one million times the radioactivity of uranium, but from the rarity of the substance and the difficulty of obtaining it in a pure form, the radium compounds which have so far been available for experiment have rarely been above a radioactivity of 7,000. The quantity of radium and radium compounds so far produced has been exceedingly small and the cost is very great. Professor Curie states that it would take five thousand tons of uranium residue to produce a kilogram of radium at a cost of about \$2,000 per ton.

Heat-Producing Properties.—Radium has the remarkable property of maintaining its temperature at about 1.5° C. above its surroundings. Heat production like light production from radium appears to be made without any change in the radium and without any loss of weight. This remarkable force production as exhibited by constant heat production can be appreciated when it is understood that radium radiates enough heat to melt more than its own weight of ice every hour, and to continue, so far as is known, this force production for an indefinite period.

Light and Fluorescence.—When a tube containing radium is viewed in the dark it is seen to emit a distinctly visible light. The light emitted is of uniform quality and is produced indefinitely, and, so far as is known, without any change in the radium itself. When the rays from radium are directed upon the double cyanide of platinum and barium, tungstate of calcium, and certain other chemicals which fluoresce under the action of the *x*-ray, the radiations from radium cause these substances to glow with a visible light; the properties of the radiations from radium in this respect being like those from the *x*-rays. A sufficient quantity of radium has never been obtained to allow of the practical use of the fluorescence so obtained in the way in which the fluoroscope is used with *x*-rays, but it is possible that with a sufficient quantity of radium a fluorescence equal to that of the *x*-rays could be produced.

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* Mallory: "Scarlet Fever. Protozoa-like Bodies Found in Four Cases." Journal of Medical Research, No. 4, vol. i., 1904.

Photochemical Effects.—When the rays from radium are directed upon a sensitized photographic plate from which all ordinary light is excluded by having the plate enclosed in a light-tight envelope, the silver salts are reduced, and an effect similar to that produced by the *x*-rays is obtained.

This photo-chemical effect appears to be identical with that produced by the *x*-rays, except that either from the radiations from radium being less powerful in photochemical effect or from a sufficient quantity of the substance not being used, the rays have not as great penetrating power. Exposures of long duration produce outlines of the human hand with but faint indications of the bones.

Like the fluorescent effects of radium the photochemical effects have not as yet been made of practical value. Practical results may, however, be possible, provided radium can be obtained in sufficient quantities and its action can be properly controlled.

Vitochemical Effects.—The effect produced by the radiations from radium on living tissue are most remarkable. These effects, in certain ways, resemble the effects produced by *x*-rays, but appear also to have peculiar properties which, so far, have not been found to be produced by *x*-rays. Radium rays, like *x*-rays, are capable of producing "burns." The discovery of this effect of radium was made by Professor Becquerel, who, when journeying from Paris to London, carried in his waistcoat pocket a small tube of radium. About a fortnight later the skin under the pocket began to redden and fall away, and finally a deep and painful sore formed which was several weeks in healing. Like the burns produced by the *x*-ray these pathologic effects of radium radiations do not appear until several days after the part has been exposed. Many other important vitochemical effects are produced by the peculiar force thrown out from this remarkable substance. Becquerel found that if seeds were exposed for a long time to the emanations from radium their germinating power was destroyed.

M. Banysz, in experiments in the Pasteur Institute, found that the emanations from radium produced remarkable effects upon rabbits, guinea-pigs, and other small animals. These experiments show that radium has the remarkable power of so interfering with organic processes as to inhibit growth and even destroy life. A small amount of radium suspended over a cage containing mice will, after a few days, cause loss of hair and blindness, followed later by death. The same experimenter reports that exposure to the radiations from radium will cause arrest of development in certain lower organic forms. He exposed the larvæ of Ephestia kuehniella in a glass flask to the emanations from radium for a few hours. After a few weeks it was found that most of the larvæ were killed, but that a few had escaped the destructive action of the rays by crawling into distant corners of the flask where they were still living, but living as larvæ; whereas in a control flask similar larvæ had changed into moths.

M. Bohn has shown that radium may so modify various lower forms of life as to produce "monsters," and he has caused remarkable deviations from the original type in tadpoles exposed to radium emanations.

The vitochemical effect of radium seems to be particularly expended upon the skin and subcutaneous tissues and the nervous system. Thus, Danysz reports that the application of a tube containing a salt of radium to the skin produces an ulcer in from eight to twenty days. A few moments' application produces congestion of the human skin. When applied to the skin of a rabbit destruction of the epidermis follows, but when applied under the skin there is only a feeble reaction on the epidermis. Danysz found that when tubes containing radium were introduced into the intestines and serous cavities of guinea-pigs very little effect was produced, but its action was noted upon the nerve centres of all animals subjected to experiment. This action, however, was comparatively feeble in those whose osseous tissues protected the nerve centres. Application of tubes containing the salt to the cranium caused paresis, ataxia, and convulsions, followed later by death.

Professor Curie introduced a few milligrams beneath the skin of a mouse over the vertebral column, causing death of the mouse in three hours.

The rays of radium have a direct effect upon the optic nerve. This was shown by Giesel, who found that when radium salts were brought near the closed eyes a sensation of light was produced. This is attributed by Hammer to phosphorescence of the humors of the eye and also to effect upon the nerves of the retina. Prof. M. Javal proposes a diagnostic use of this phenomenon, and suggests that blindness with alteration of the retina can be distinguished from that due to glaucoma or corneal opacity, because patients with the latter condition see rays from radium as well as those of sound vision, while patients who have alteration of the retina have no sensation of light when a salt of radium is placed near the eyes.

Therapeutic Uses.—The vitochemical action of radium is so like that of the *x*-rays that its use for the cure of conditions for which the *x*-rays have been used was at once suggested. Experiments seem to show that the vitochemical action of the rays of radium are much more powerful than those of *x*-rays. There seems every probability, when radium can be produced in sufficient quantity and its action properly controlled, that it will be a valuable therapeutic agent. So far, its use has been mainly confined to the treatment of lupus, epithelioma, and superficial skin diseases. Favorable reports of results of its use in these diseases have been given by a number of clinicians. Danlos reports a case of lupus of the face, exposed to the action of a salt of radium which had a radioactivity of 19,000 for from twenty to thirty-six hours, with the result of the disappearance of the disease and with the formation of a smooth, white cicatrix. Other clinicians have reported equally favorable results and have called attention to the good effect as shown by the smooth, soft, and white resulting scar.

For therapeutic use the radium compounds have in some cases advantages over the *x*-ray. In superficial diseases of the skin and mucous membrane these radium compounds, being enclosed in small hermetically sealed glass receptacles, can readily be employed as therapeutic agents. All that is necessary is to place the receptacles containing the compound in close apposition to the parts, so insuring a local action. Furthermore, radium compounds being permanent these glass receptacles can be used for an indefinite time in any number of cases, and this apparently with more surety of definite results, so far as tissue reactions are concerned, than can be obtained from the radiations from *x*-ray tubes.

William Cline Borden.

SKIN AND ITS APPENDAGES: ANATOMY.—The skin, or integumentum commune, of the body acts as a covering and a protection for the deeper portions, besides being an organ of secretion, of excretion, of special sense —the sense of touch,—of common sensation, and the conservator of animal heat. Embryologically, it is developed from those two primitive layers of the blastoderm, the ectoderm and the mesoderm, which are formed by the cellular division of the impregnated ovule. The epidermis, or most external layer of the skin, is formed from the ectoderm, while a superficial portion of the mesoderm furnishes the remaining constituent parts—the corium, or cutis vera, and the subcutaneous or fatty tissue.

General Characteristics.—When fully formed the skin can be regarded as a completely closed sac, which

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